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OBSERVATION OF THE BEHAVIOR OF RATS RUNNING
TO REWARD AND NONREWARD IN AN ALLEYWAY

by

John Edward Kello

Department of Psychology
Duke University

Date:

June 21, 1973

Approved:

J. E. R. Staddon

J. E. R. Staddon, Supervisor

Maryann Johnston

Leslie E. Eisele

G. R. Fekken

Robert H. Meyer

Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor
of Philosophy in the Department of
Psychology in the Graduate School
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1973

ABSTRACT

(Psychology-Experimental)

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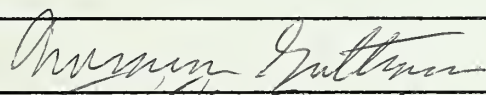
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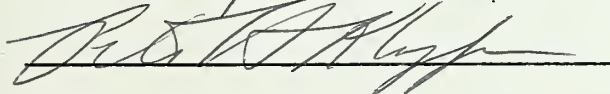
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ABSTRACT

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The first experiment sought specifically to determine whether variations in rats' overall run time in the alleyway reflect variations in the vigor of a single response, running (Hullian S-R view), or variations in the frequency of running relative to other, competing, behaviors, and not in the vigor of running ("response-competition" view). More broadly, the goal was a detailed descriptive account of the alleyway behavior of individual rats under a variety of typical experimental conditions.

Six 23-hr. hungry rats were run for 75 trials in an alleyway to various amounts of reward, and the amount was shifted at several stages of training. Also, an environmental stimulus change was introduced during training. Six 23-hr. thirsty rats were run under comparable conditions. Overall run time was recorded and each trial was video-taped. Each run was then classified as a competing behavior trial (subject ceases forward progress after entering alleyway), an accessory behavior trial

(subject shows some additional behavior while running forward, but no full competing behavior), or a direct run trial (only running occurs).

The primary results were: (1) the decrease in run time in acquisition for each subject was due mainly to an orderly decrease in the amount of competing and accessory behavior, but the vigor of running also increased; (2) large changes in run time with other manipulations (differences in amount of reward in acquisition, shifts in amount of reward, extra stimulus, and proximity to reward) also reflected changes in amount of competing and accessory behavior, and smaller changes in the vigor of running; (3) the behavior of the thirsty rats was qualitatively the same as the behavior of the hungry rats, but was less affected by reward. The thirsty rats ran slower and showed more overall variability and more competing and accessory behavior than the hungry ones.

The main implication of these results is that the alleyway is a multiple-response, selective-learning situation in which running both increases in vigor and gradually replaces other behaviors.

The second experiment examined the structure of behavior in extinction to determine whether the increase in run time with nonreward reflects a return of competing and accessory behavior in the absence of selection for running. Secondary questions, not critical to a selective-learning view of the alleyway, were: (1) Would the addition of extra stimuli in acquisition which encourages competing behavior delay the return of high levels of competing behavior in extinction? (2) Does partial reinforcement

in acquisition, which does retard extinction, do so through an increase in competing behavior in acquisition?

Ten 23-hr. hungry rats were run in the alleyway to continuous reward (CRF), continuous reward with extra stimuli (CRF-S), or partial reward (PRF), for 59 trials. All were then run for at least 18 non-rewarded trials in extinction.

The primary results were: (1) extinction following continuously rewarded acquisition did reflect a great return of competing and accessory behavior, of the same form as early in acquisition, consistent with the view of the alleyway as a selective-learning situation; (2) CRF-S rats showed slightly greater resistance to extinction than CRF rats; (3) the great resistance to extinction of the PRF rats was not a function of high levels of competing and accessory behavior in acquisition; (4) the PRF subjects showed much competing and accessory behavior and slow running in latter parts of the alleyway, and some continuously rewarded subjects showed similar behavior. This, plus observations in both experiments of recurrent behavior sequences across subjects and periods of atypically long run times for several subjects, suggests that an individual rat's behavior is not entirely independent of the behavior of other subjects run concurrently, though the mechanism underlying these interactions is not understood.

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My wife Meg helped with coding the raw data of Experiment II, preparing and checking rough figures and tables for both experiments, and critically reading parts of the manuscript. Less tangibly, she has helped through understanding, patience, and forbearance beyond all reason. There are no words to thank her.

J. E. K.

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INTRODUCTION

In the familiar instrumental conditioning alleyway situation with rats, it is widely assumed, especially by S-R theorists following Hull (1943), that overall run time directly reflects the vigor of a single response, running. Presumably, when overall run time is longer, e.g., early in training, the rats are simply running more slowly (King, 1959; Logan, 1959; Marx & Brownstein, 1963; Spence, 1956). However, little attention has been given to actually determining the form of the response measured by overall run time. S-R theorists sometimes acknowledge that behavior other than running may occur, especially early in training and during extinction, as incidental observations throughout the alleyway and maze-learning literature suggest (e.g., Bruce, 1935, 1937; Campbell & Meyer, 1971; Crespi, 1942; Graham & Gagné, 1940; Hammer, 1971; Hicks, 1911; Miller & Miles, 1936; Miller & Stevenson, 1936). When time-consuming "competing" behavior is occurring, the overall run time measure would obviously not directly reflect the rate of running. But, at least during continuously rewarded training, S-R theorists consider competing behavior an infrequent nuisance, extraneous to the basic process of learning demonstrated in the alleyway, viz., the gradual strengthening

(increase in speed) of a single response (running) with practice (Spence, 1956, pp. 37-39, 116-117; 1958, p. 74; 1960, pp. 122-123). The free-operant Skinner box situation is also widely considered to allow study of the strengthening of a single response in relative isolation (cf., Skinner, 1938, p. 55).

On the other hand, some theorists have argued that every learning situation is a multiple response situation, and that instrumental responses such as running are "all-or-none" responses without an intensity, or amplitude, dimension (Bindra, 1961; Estes, 1950, 1959; Guthrie, 1959; Knarr & Collier, 1962; Premack, 1965). In this view a long run time would reflect, not slow running, but a low relative frequency of "bursts" of running at a constant intra-burst rate, and a corresponding high relative frequency of competing behavior. Acquisition in the alleyway would consist of an increase in the relative frequency of running at the expense of competing behavior rather than an increase in the rate of running; extinction would reflect an increase in the frequency of competing behavior and a decrease in the frequency of running, rather than a decrease in the rate of running. According to this general "response-competition" account (Bindra, 1961; Estes, 1950, 1959; Guthrie, 1935, 1959), competing behavior is not random "noise," to be eliminated or at least ignored (cf., Spence, 1956, 1960), but is an orderly and integral part of instrumental learning and performance.

A handful of alleyway experiments directly concerned with the role

of competing behavior in continuously rewarded instrumental learning and performance offer some support for the response-competition view.¹

They have shown that competing behavior is not infrequent and limited to early stages of acquisition, but may occur throughout training. Further, they have established that the decrease in overall run time in acquisition, and with larger reward or more severe deprivation, is accompanied by a corresponding decrease in the amount of competing behavior (Bindra, 1963; Cicala, 1961; Cotton, 1953; Kello, unpublished experiment; King, 1959; Marx & Brownstein, 1963; McCoy & Marx, 1965; Pereboom & Crawford,

¹Although the main concern here is with alleyway experiments, there are also data in the free-operant literature which strongly support the response-competition view. Thus Gilbert (1958) showed that the differences in overall rate of bar-pressing in highly trained rats as a function of percent concentration of sucrose were due almost entirely to differences in the amount of time spent responding. When a rat was responding it bar-pressed at a nearly constant rate regardless of the magnitude of reward; at higher magnitudes it simply responded for a greater proportion of the total time (more frequent response bursts, longer bursts, shorter pause between bursts). Similarly, Blough (1963) found that under a wide range of conditions, including changes in the length of the average interreinforcement interval, stimulus generalization tests, and extinction, pigeons responded at a basic within-burst rate of 2-3 keypecks per sec. When overall rate changed, this basic rate remained the same, but the latency to bursts and the frequency and duration of bursts changed appropriately. (See also arguments by Baum & Rachlin, 1969; Catania, 1961; Premack, 1965; Premack & Schaeffer, 1962; Rachlin, 1972.)

Although it is sometimes explicitly assumed in free-operant work that when bar-pressing or key-pecking are not occurring some other (competing) behavior is (cf., DRO schedules, Reynolds, 1961), operant studies dealing with the structure of overall response rate have not focused on competing behavior. Overall response rate in these studies is analyzed in terms of bursts of operant responses and "pauses." The highly automated free-operant methodology has encouraged observation of behavior even less than the discrete-trials alleyway approach (cf., Skinner, 1938, pp. 58-59).

1958; Smoot, 1964). However, each of these studies which has examined a "pure" measure of running with competing behavior eliminated (all but Bindra, 1963, and McCoy & Marx, 1965) has found significant, though smaller, changes in this measure as well. The studies differ widely in the extent to which variation in the amount of competing behavior alone can account for the variation in the overall run time measure.

Several weaknesses in these studies suggest that the obtained changes in the vigor of running without competing behavior may be artifactual, and therefore that a simple response-competition view may best account for alleyway learning and performance. Two of the studies suffered quite obvious measurement defects (cf., Marx & Brownstein, 1963). Cotton (1953) found that, while the decrease in overall run time with an increase in hunger drive was largely due to a decrease in the amount of competing behavior, the vigor of running without competing behavior also increased within a narrow range. However, Cotton reports that under the milder deprivation conditions a high proportion of the fastest trials, presumably with no competing behavior, was lost due to subjects' jumping over photocells. This was particularly the case for 0-hr. deprivation, with up to 22.5% of the fastest trials being lost for some subjects. And although it is not reported which levels of deprivation differed significantly from each other in terms of vigor or running, inspection of Cotton's Fig. 1 (1953, p. 192) suggests that the overall significant differences were probably due entirely to the longer times at 0-hr. deprivation.

Pereboom and Crawford (1958) found small but significant changes in the pure measure of the instrumental response both in acquisition and as a function of reward magnitude. In their study, however, when a subject retraced, the time taken for him to return to where he had initially stopped and turned around was included in the measure of the instrumental response for that trial. Given that retracing is more frequent early in training and with small reward, "pure" run time would obviously be longer under these conditions whether subjects actually ran more slowly or not, as Pereboom and Crawford acknowledge.

A central problem with each of the available studies of alleyway competing behavior is that little attention has been paid to specifying clearly what constitutes competing behavior, and then to applying the criteria uniformly (cf., McCoy & Marx, 1965, p. 356). The criteria that have been used vary extensively from study to study, and probably do not in any case encompass all behavior incompatible with forward progress in the alleyway. Even the fundamental criterion of competing behavior, viz., that the subject stop, is not always explicit (e.g., Pereboom & Crawford, 1958). At any rate, since defining properties of criterial behaviors are almost never given, it is not always clear what constitutes a stop and what proportion of the stops in one study would be rated as stops in another study. Also, since trials were never filmed or video-recorded in these studies, there was no way to review difficult decisions, and no way to ensure that application of the criteria for competing

behavior, whatever they were, did not change in the course of the experiment as the observer became more familiar with the behavior of rats in alleyways. It is likely then that some indeterminate amount of the obtained variation in the vigor of running in each of these studies can be attributed to including time-consuming competing behavior in the "pure" measure of running.

It has also been suggested that there is an intermediate class of "competing" behavior which is not overtly incompatible with running, but which may occur concurrently with running and slow it down, e. g., sniffing the floor while running forward (Kello, unpublished experiment; Marx & Brownstein, 1963; Pereboom & Crawford, 1958; Smoot, 1964). This behavior has not been separately studied, due to difficulties in specifying it (Marx & Brownstein, 1963, p. 188). With the possible exception of the King (1959) experiment, it has simply been included in the "pure" measure of running. If this behavior occurs where full competing behavior is likely to occur, then including it in the "pure" measure of running would further spuriously amplify the changes seen in this measure.

A final specific weakness of these studies of competing behavior in the alleyway is that two different pure measures of the instrumental running response have been used: a "forward progress" measure, which equals the total time on a trial minus the time spent in competing behavior (King, 1959; Marx & Brownstein, 1963; Pereboom & Crawford, 1958; Smoot, 1964), and a "direct run" measure, which is simply the total time

on those trials on which no competing behavior occurs (Cicala, 1961; Cotton, 1953; Marx & Brownstein, 1963). The two measures are not strictly comparable. It has been shown that the direct run measure varies much less than the forward progress measure, and it has been argued on several grounds that direct run time is a clearer measure of running without competing behavior than is forward progress time (Kello, unpublished experiment; Marx & Brownstein, 1963).

The first experiment sought to correct the deficiencies of previous studies of alleyway competing behavior, with rigorous and uniformly applied criteria of competing behavior and the instrumental response. The purpose was to determine whether changes in competing behavior alone can account for changes in overall run time, as the response-competition view claims. Also, the range of variables to which this general type of analysis has been applied was extended in this experiment.

There are two more general problems with the previous studies of competing behavior to which the first experiment was also addressed. First, it is not clear to what extent the results describe the behavior of any single subject. Alleyway studies have traditionally dealt with group-averaged data, and the studies of competing behavior discussed here are no exception. It is generally conceded that it is impossible to argue from group-averaged curves to single-subject behavior, though quite simple to argue in the reverse direction (Bakan, 1954; Estes, 1956; Hayes, 1953; Sidman, 1952; Spence, 1956). Yet, it is also quite clear that learning

theorists intend their statements to apply to the behavior of single subjects (Estes, 1956; Hayes, 1953, p. 269; Skinner, 1961; Spence, 1956, pp. 60-61). Thus while interested in the behavior of the individual, learning theorists' accounts of behavior in the alleyway are based almost entirely on group-averaged data, which may not in fact accurately represent the behavior of any individual subject (cf., Rashotte, Adelman, & Dove, 1972). It should be clear that the role of competing behavior in instrumental learning and performance can be understood only through an analysis of the behavior of individual subjects.

A second problem is the lack of direct observational study of the whole range of behavior in the alleyway, and in other learning situations (Bindra, 1961; Guthrie, 1959; Mackintosh, 1955; Staddon & Simmelhag, 1971; but see Zener, 1937). The only interest in alleyway competing behavior has been to identify it in order to remove it, to determine whether a pure measure of the instrumental response varies with the overall rate measure. In the absence of a careful, direct observational analysis of the structure of alleyway behavior, basic questions remain as to what competing behavior is, and how orderly it is, common assumptions being that it is simply "random" or "spontaneous" activity (see Bindra, 1961; Hicks, 1911; Spence, 1956), or behavior directly elicited by novel stimuli (Bindra, 1961; Hinde, 1970; Mackintosh, 1955; Pereboom, 1957; Spence, 1956).

Most broadly stated, the aim of the first experiment was to provide

a descriptive account of the trial-by-trial behavior of individual rats running to reward in the alleyway under a variety of experimental conditions, to better understand the form and nature of competing behavior in the alleyway, as well as its role in determining measured overall run time.

EXPERIMENT I

The first experiment studied the behavior of individual rats running to reward in an alleyway as a function of number of rewarded trials (acquisition), amount of reward during acquisition, shifts in amount of reward, proximity to reward, and deprivation state and associated reward. The last three variables require further comment.

Reward magnitude shifts. When amount of food reward is increased or decreased in the alleyway situation, overall run time has been found to change abruptly in the appropriate direction (Crespi, 1942; Zeaman, 1949). It has been argued that, along with other variables which affect the overall run time measure, the effects of shifts in reward magnitude may be mediated through competing behavior and not by changes in the rate of running (Hammer, 1971; Pereboom, 1957; Pereboom & Crawford, 1958). There is some informal evidence that downshifts in amount of reward may indeed engender competing behavior in the alleyway and that upshifts may reduce or eliminate it (Crespi, 1942). But the role of competing behavior in reward magnitude shift effects has not been studied directly, and it is therefore not clear to what extent competing behavior alone can account for these changes in overall run time.

The classical studies showing large and abrupt changes in run time with changes in reward magnitude generally shifted after 15-25 trials at 1 trial per day. A recent study of magnitude shift effects which shifted after 50 trials at 1 trial per day found that at this late stage of training a 25-fold increase in amount had only a very slight, though consistent, effect on early segment start and run time; a comparable decrease in amount engendered only a slight and transient increase in run time (Hammer, 1971). Hammer informally observed that the subjects receiving small reward exhibited much competing behavior early in training. Although no quantitative data were presented, she suggested that the long and variable run times of the small reward subjects were due to this competing behavior. She also observed that later in training, when this behavior had dropped out for the small reward subjects, their run times were consistent and very close to the asymptotic level attained (much earlier in training) by the large reward subjects. Hammer argued that, since run time given no competing behavior does not differ greatly for large or small reward subjects (cf., also Pereboom & Crawford, 1958), large and abrupt changes in run time with reward magnitude shifts early in training must reflect changes in the amount of competing behavior. Later in training, when competing behavior has dropped out and only the relatively invariant instrumental response is occurring, magnitude shifts will have little effect.

In light of Hammer's hypothesis, the present experiment ran rats to "large," "medium," and "small" amounts of reward and shifted at various

stages of training, looking at both running and competing behavior throughout. The purpose was to determine whether large-scale changes in overall run time with reward magnitude shifts reflect changes in competing behavior and not in the vigor of running, and whether such changes occur early but not late in training.

Proximity to reward. Although the locus of alleyway competing behavior has not been studied directly, it has been suggested that in some situations competing behavior tends to occur mainly in early parts of the alleyway, farthest from reward (Bindra, 1963; Marx & Brownstein, 1963; Miller & Miles, 1935), and incidental observations throughout the literature support this suggestion (Bruce, 1937; Campbell & Meyer, 1971; Crespi, 1942; Hammer, 1971; Hicks, 1911; Kello, unpublished observation). One obvious implication of these observations is that the "goal gradient" (Hull, 1934), viz., faster run time closer to the goal, may be an "artifact" of competing behavior (King, 1959; Marx & Brownstein, 1963). Data presented by King (1959) offer some support for this possibility, although this experiment suffered the weaknesses outlined previously (pp. 4-8). King showed that the slope of the goal gradient was reduced when competing behavior was eliminated, but there were no data on the locus of competing behavior. Further evidence that the goal gradient may be due to an early segment bias of competing behavior comes from observations that the gradient is sharpest early in training and with smaller reward (Bruce, 1937; Crespi, 1942; Hull, 1934), and that a sharp goal gradient returns

early in extinction (Hull, 1934; Miller & Miles, 1935). All these situations presumably involve a high level of competing behavior.

The present experiment examined the locus of competing behavior and the role of competing behavior in determining the goal gradient.

Deprivation state and associated reward. Most laboratory studies of learning and performance in animals, including those discussed here, have used hungry animals responding for food. The results of such studies have been generalized freely to other "need-reinforcer" relationships under two related assumptions: (a) that all "drives" have equivalent effects on behavior (Brown, 1961; Campbell & Cicala, 1962; Petrinovich & Bolles, 1954; Tapp, 1969), which is implicit in Hull's (1943) "big D," generalized drive; (b) that all reinforcers operate in the same way in all learning situations (Seligman, 1970; Shettleworth, 1972; Teitelbaum, 1966). These assumptions have been borne out in many situations for thirsty animals performing for water (e.g., Jenkins & Arnold, 1968; Kintsch, 1962; McCoy & Marx, 1965; Skinner, 1938; Weinstock, 1958; Zimmerman, 1971), in that results comparable to those with hungry, food-rewarded subjects are found. But in some cases, which have received little attention (cf., Shettleworth, 1972), the results are not the same. For example, it appears that simultaneously food- and water-deprived rats running to water in an alleyway may show no "frustration effect" (Levy & Seward, 1969), and thirsty rats may show only a very slight decremental effect of long delays of water reward in the alleyway (Logan & Spanier, 1970).

Also, in the free-operant bar-pressing situation there may be no "partial reinforcement effect" with water (Macdonald & de Toledo, 1972).

There are several other lines of evidence suggesting behavioral differences between hungry, food-rewarded and thirsty, water-rewarded animals. Thus it has been shown that it is easier to train hungry than thirsty rats to alternate for reward in a T-maze, while thirsty rats form a position habit more readily than hungry ones (Bolles, 1958a; Petrinovich & Bolles, 1954). In a number of "general activity" situations (e.g., running wheel, stabilimeter cage, bar-pressing for light), thirsty rats show much less activity than hungry rats deprived for the same number of hours or at the same percentage of ad lib body weight (Campbell & Cicala, 1962; Hall, 1955; Tapp, 1969). Also, in an alleyway study using thirsty rats, Kintsch (1962) incidentally reported observing very little competing behavior, even with minimal deprivation and small reward. These results suggest overall that thirsty rats may show less variability in their behavior than hungry rats. On the other hand, Bruce (1935) found that 24-hr. thirsty rats clearly showed more variability and performed more poorly throughout training in a multiple unit maze than 24-hr. hungry rats. And at least two alleyway experiments dealing with competing behavior have reported, contrary to Kintsch (1962), that competing behavior does occur throughout training for thirsty rats (Bindra, 1963; McCoy & Marx, 1965).

The present experiment examined the behavior of thirsty rats running to water under the same conditions as the hungry rats running to

food, comparing the running and competing behavior of the two groups at each stage of training. It has not previously been determined to what extent competing behavior can account for variations in overall run time for thirsty rats running to water with any of the variables studied here. Further, it was of interest to see if the categories of behavior shown by thirsty subjects would differ from those shown by hungry subjects (cf., Petrinovich & Bolles, 1954; Shettleworth, 1972; Tapp, 1969).

Method

Subjects

The subjects were 12 male Long-Evans hooded rats, approximately 100 days old on experimental day 1.

Apparatus

The subjects were run in a straight alleyway, 1.90 m. long from the start door to the last photocell, with internal dimensions of 12.7 cm. by 12.7 cm. The apparatus was constructed of plywood and was covered throughout with a hinged top of clear Plexiglas. Attached to the alleyway proper were a 22.9 cm. long startbox (SB) and a 20.3 cm. long goalbox (GB), both L-shaped. The floor of the entire apparatus was painted a dull white. The walls of SB were painted flat black, while the walls of GB and the alleyway were left unpainted. Four pairs of photocells and light sources were spaced at 61-cm. intervals in the alleyway, dividing it into three consecutive 61-cm. (2 ft.) segments, A_1 , A_2 , and A_3 , from SB to

GB. The first photocell was placed 7.0 cm. from the clear Plexiglas guillotine-type start door which separated SB from the alley. A similar Plexiglas door was located in A_3 , 8.9 cm. before the last photocell. This door, normally up, was dropped to prevent retracing after a rat had entered GB. Both doors were operated manually, by strings. The photocells were wired to Standard electric timers to give run times accurate to .01 sec. for each of the three segments of the alley.

The alleyway was illuminated by an overhead incandescent light fixture, shielded by white Plexiglas, and running the length of the apparatus. The output of this fixture was reduced so that illuminance throughout the alleyway at floor level was quite dim (2.1-2.3 ft. candles), but sufficient for video-recording. Masking noise (speech noise) was on continuously during sessions, at 70 db.

A Concord TV camera was mounted from the ceiling in line with the alleyway, 61 cm. behind the end of GB and approximately 1.90 m. up from the floor. The swivel mounting allowed the camera to sweep down the length of the alleyway to continuously follow subjects' movements throughout. A mirror was mounted above and behind SB so that the subjects' movements in SB, partly obscured from direct camera view, could be continuously monitored. A white curtain was suspended approximately 61 cm. behind GB such that the experimenter's movements in operating the camera and the start and retrace doors were concealed from subjects in the alleyway. The camera was connected with a Concord video-tape

recorder and monitor.

The alleyway and all associated recording equipment were located in a semi-soundproof experimental room some distance away from the animal colony.

Pretraining

After arrival in the laboratory the subjects were kept in individual cages in 24-hr. light throughout the experiment. For 6 days they were given ad lib food (Purina chow) and water, and were handled for 2-3 min. and weighed daily. The subjects were then randomly divided into two groups, "hungry" (Gp H) and "thirsty" (Gp T). From the 7th day of pre-training to the end of the experiment, Gp H was fed only for 1 hr. per day, and Gp T was watered for only 1 hr. per day. Gp H had continuous access to water and Gp T had continuous access to food. On day 7 both groups were separately transported in their home cages, without food or water, to the experimental room, at the same time of day as they would later be run in the experiment proper (Gp H at 9:00 a.m. and Gp T at 11:00 a.m.). They were exposed to the experimental room, which was set up for an experimental session, and to typical within-session equipment noises such as the activation of the photocell-clock circuitry, operation of the guillotine doors, and operation of the TV camera and video-tape recorder, intermittently, for 1-2 hr. Pretraining days 8-16 differed from day 7 only in that subjects were also handled and gentled in the experimental room on

these days. The rats received their 1-hr. daily ration of the appropriate deprived substance approximately 10-15 min. after they were returned from the experimental room to their colony. Body weights were monitored daily throughout the experiment.

Experimental procedure

Prior to the start of experimental training, subjects within the two groups were randomly assigned to either of three reward magnitudes -- large, medium, or small. For Gp H, small reward was 1 .045 g. Noyes pellet, medium was 4 pellets (.18 g.), and large was 16 pellets (.72 g.). For Gp T, small reward was 2 drops (.17 ml.) of cool water from a standard eyedropper, medium was 6 drops (.50 ml.), and large was 18 drops (1.5 ml.). There were two rats in each group at each of the three reward magnitudes. The particular magnitudes used for large, medium, and small were selected on the basis of work with pilot subjects, which showed that the consummatory times for food and water at each of the three levels were approximately equivalent. Rewards were presented in food cups, which were placed in the short arm of GB and were not visible from the alley.

On experimental day 1 each subject was run one trial to the appropriate magnitude of the appropriate reward. One trial was also run on day 2, and two trials on each of days 3 and 4. Thereafter, three trials per day were run, to the conclusion of the experiment at day 27. Within

each of the groups the daily running order of the six subjects was randomized. On each experimental day a group was brought to the experimental room, in which all equipment which would be operating during the session was on, and was left for a minimum of 10 min. while the floor of SB, GB, and the alley were sponged with a weak solution of Lysol cleaner in warm water, then dried with paper towels. At the beginning of a trial the appropriate subject was placed into SB by hand. The experimenter quickly turned on the video-recording equipment and positioned himself behind the curtain. From here he operated the camera and the start and retrace doors. When the rat had been in SB a minimum of 10 sec., and had been near the start door and oriented toward it for 3 sec., the start door was raised. If the subject began retracing back to SB after entering the alleyway, the start door was quietly lowered to prevent his reentry into SB. When the rat activated the last photocell and entered GB, the retrace door was dropped behind him and the video-recording equipment was turned off. After consuming the reward, the subject was immediately removed from GB and returned to his cage. Times were recorded, clocks reset, GB baited, and the floor of the apparatus was again sponged with Lysol and dried. The intertrial interval for a given subject was always 15-21 min. Prior to each session the water was removed from the cages of Gp H, and the food was removed from the cages of Gp T. After a session the subjects were returned to the colony, where Gp H was again given ad lib water, and Gp T ad lib food. After approximately 5 min. the subjects

receiving small and medium amounts of reward were fed or watered the difference between the amount they had just received in the alleyway and the amount the large-reward subjects had received, in order to control for differential weight gain. Ten min. after this had been consumed, all subjects were allowed 1-hr. access to the appropriate deprived substance.

At trial 25 one of the small-reward subjects in Gp H and one in Gp T, randomly selected prior to trial 1, were shifted to the large reward magnitude (see Fig. 1 for the reward magnitude of each subject throughout training). Similarly, one of the two large reward-subjects in each group was shifted to the small amount at this stage of training. All subjects were then run to trial 54 with no further change in reward conditions. However, immediately after the session ending with trial 33, insecticide was sprayed in parts of the experimental room. This change in stimulus conditions affected the subsequent behavior of some of the rats in the alleyway such that it was not possible to obtain relatively stable individual run times, desired before the next shift in reward magnitudes, until around trial 45-54. At trial 55 all of the rats were shifted to a small or large amount. The previously unshifted large-reward subject in each group, the subject shifted to large reward at trial 25, and one of the two medium-reward subjects chosen at random were all shifted to the small amount; the previously unshifted-small reward subject in each group, the subject shifted to small reward at trial 25, and the remaining medium-reward subject were all shifted to the large amount. Again at trial 67, all of the

Fig. 1. Reward Magnitude for Each Subject Throughout Training.

Subjects		Trials			
		1 . . .	25 . . .	55 . . .	67 . . . 75
Gp H	101	(sm) →	(lg) →	(sm) →	(lg) →
	109	(sm) →	(lg) →	(sm) →	
	105	(med) →	(lg) →	(sm) →	
	113	(med) →	(sm) →	(lg) →	
	108	(lg) →	(sm) →	(lg) →	
	110	(lg) →	(sm) →	(lg) →	(sm) →
Gp T	102	(sm) →	(lg) →	(sm) →	
	112	(sm) →	(lg) →	(sm) →	(lg) →
	103	(med) →	(sm) →	(lg) →	
	107	(med) →	(lg) →	(sm) →	
	106	(lg) →	(sm) →	(lg) →	(sm) →
	111	(lg) →	(sm) →	(lg) →	

subjects currently receiving small reward were shifted to large, and vice versa. All were run to the conclusion of the experiment at trial 75 under these reward conditions. Thus some small- and some large-reward subjects were shifted early, and all of the subjects were shifted at middle and late stages of training.

Data analysis

In addition to the automatic recording of the overall run time separately for each of the three alleyway segments, each trial was videotaped. Table 1 presents a system for categorizing the alleyway behavior of rats, which accounted for virtually all of the subjects' within-trial time in pilot observations (Kello, unpublished experiment) and in the present experiments. Based on this system, each trial was classified as either of three mutually exclusive and exhaustive types. A trial on which a stop, hesitate, or freeze occurred between the first and last photocells, and thus the subject's hind legs ceased forward progress, was scored as a full competing behavior (CB) trial; a trial on which the subject elongated from the start-box and activated the first photocell before moving his hind legs was also scored as a CB trial. A trial on which no stop, hesitate, freeze, or initial elongation from SB into A_1 occurred, but on which the subject showed some other classifiable behavior concurrently with running to GB, e.g., AH, S(F), S(W), was scored as an "accessory" behavior (AB) trial. A trial on which the subject showed only running, and no classified

Table 1
Major Categories of Alleyway Behavior

Code	Meaning	Description
<u>Gross bodily movement:</u>		
Ru	Run	Locomoting through alleyway, hindlegs moving continuously.
ST [b] ^a	Stop	Cessation of running. No forward movement of the hindlegs for at least .5 sec. Forelegs also stationary.
H [d]	Hesitate	Similar to a stop. Both rear legs stationary, but for less than .5 sec. Forelegs sometimes still moving forward, body elongating slightly.
AH	Accessory hesitate	Abrupt slowing of forward progress. Almost a full hesitate, but forward movement of the hindlegs does not stop. Forelegs may be momentarily stationary.
E [e]	Elongation	A pronounced stretching forward of the front part of the body with rear legs stationary, particularly seen upon leaving SB.
T 1/4; T 1/2 - ret. [m;n]	Quarter turn; half turn and retrace	Following a stop, a change in the direction of the rear legs. T 1/4 = turn 90 deg. from direction of forward progress, or any turn occurring when the first photocell has been activated but the rat's body is not yet entirely in A ₁ . T 1/2 - ret. = reverse direction and retrace after entry into A ₁ .
F [o]	Freeze	Like a hesitate or stop, but with the body noticeably stiffened, often elongated, and completely motionless. Generally no vibrissae movement. The animal often jerks into this characteristic posture.

Receptor-orienting activity:

S(F)	[a]	Sniff floor	Nose to floor, often apparently in contact, with characteristic vibrissae movement. Frequently accompanied by side-to-side head movements. By far the most frequent receptor-orienting activity.
S(W)	[c]	Sniff wall	Sniffing with nose oriented to a wall.
S(C)	[f]	Sniff center	Sniffing in center of the alleyway.
S(T)	[j]	Sniff top	Sniffing the plexiglas top of the apparatus.
S(DW)	[i]	Sniff doorway	Sniffing oriented toward doorway for start door or retrace door.
S(P)	[g]	Sniff photocell	Sniffing in holes for photocells or light sources.
R(W)	[h]	Rear at wall	Rat oriented toward a wall, sitting on haunches, with both forepaws off the floor, and often in contact with wall. Frequently accompanied by wall sniffing.
R(C)	[q]	Rear in center	Forelegs off the floor, body oriented in direction of the goalbox.
R(T)	[p]	Rear at top	Rearing with head oriented to top of the apparatus, often accompanied by S(T).
R(DW)	[l]	Rear at doorway	Rearing in a doorway, often with forepaws in contact with doorway.
Fa-(r, l)	[k]	Face right or left	Swinging head 45-90 deg. from direction of forward progress to right or left. Often seen as rat passes a photocell light.

^aLower case letters in brackets refer to the code used for competing behaviors in the figures for both experiments. The order of the letters reflects the overall relative frequency of the corresponding competing behavior category in Experiment I.

competing or accessory behavior between the first and last photocells marking off the alley proper, was scored as a "direct run" (DR) trial. A trial on which competing and accessory behavior both occurred was scored simply as a CB trial.

From the video-tape recordings a graph was made of each trial for every subject. On a schematic "map" of the alleyway, each behavior category which occurred was plotted at the appropriate locus, and it was noted whether the behavior was competing or accessory. Receptor-orienting activities were competing if they occurred while the subject's rear legs were stationary, and accessory if they occurred while the rear legs were moving forward. The amount of time spent in competing behavior per CB trial was measured from the recordings with a stopwatch. Behavior occurring at a photocell was counted as occurring in the alleyway segment begun by that photocell. Thus if a subject stopped and sniffed the second photocell, thereby activating it, this competing behavior was scored for A_2 , even if most of the subject's body was still in the latter part of A_1 . Behaviors in SB prior to a trial, in the 7.0 cm. segment between the start door and A_1 , and during retraces were recorded on the maps but were not used in classifying trials, or in determining any of the data presented here. It was also noted for each trial whether the subject showed a galloping gait, with both front and both hind legs moving together in unison, or some other gait ("run"). With the present video-recording system, and in the absence of clear guidelines for classifying rat gaits (cf., Gray, 1968),

finer gait differentiations could not be made reliably.

When there was some doubt on a given trial as to how an observed behavior should be categorized ($< 5\%$ of all recorded behaviors), the tape was reviewed and compared with other trials, already analyzed, showing similar behavior. When some doubt remained even after such review ($< 15\%$ of all such cases) as to whether a behavior should not be counted or should be counted as accessory behavior (e. g., jerky head-movements while running, abrupt changes in gait), or as to whether a behavior was competing or accessory (e. g., H or AH?), a conservative criterion of behavior other than running was used; decisions between AB and no AB were resolved in favor of no AB, and decisions between CB and AB in favor of AB.

Another observer, with some training in the use of the present classification system, but with no knowledge of the conditions of the experiment, independently graphed the first six trials for every subject, and also graphed selected later trials for some subjects. In all cases there was virtually complete agreement as to whether a given observed behavior was competing or accessory ($> 95\%$) and as to precise locus ($> 98\%$), and almost as high a level of agreement as to the specific category ($> 90\%$). Agreement on gait classification (gallop or "run"), based on a sample of 15 trials for each subject, was $> 95\%$. All disagreements were resolved by reexamination of the video-tapes.

Each trial was reviewed on video-tape by the experimenter at least

seven times, including a minimum of three times after every other run had been graphed at least in a preliminary way, to ensure uniform application of the classification system throughout the experiment. Also, each run was reviewed again after every trial for Experiment II had been graphed.

Results

Acquisition

Figure 2 presents a description of alleyway behavior during acquisition up to the first change in conditions (trials 1-25 for the early-shift subjects, trials 1-33 for the others) for each individual in Gp H, and Figure 3 presents similar data for Gp T. For each subject the amount of reward in acquisition is shown. The description in these figures proceeds from a gross level in the top panel to a more molecular level in the lower panels. The top panel for each subject shows the overall run time on each acquisition trial. Run times greater than 25 sec. are plotted at 25 sec. The three types of trials are coded separately with small dots representing CB trials; filled squares, AB trials; and open circles, DR trials. The second and third panels show the duration of competing behavior and the number of bouts of competing behavior on each CB trial. The duration of competing behavior is shown to the nearest second, except that all durations less than 0.5 sec. are plotted at 1 sec. A bout began when the subject elongated out of SB into A₁ or hesitated, froze, or stopped after entry

Fig. 2. Behavior in Acquisition for Gp H.

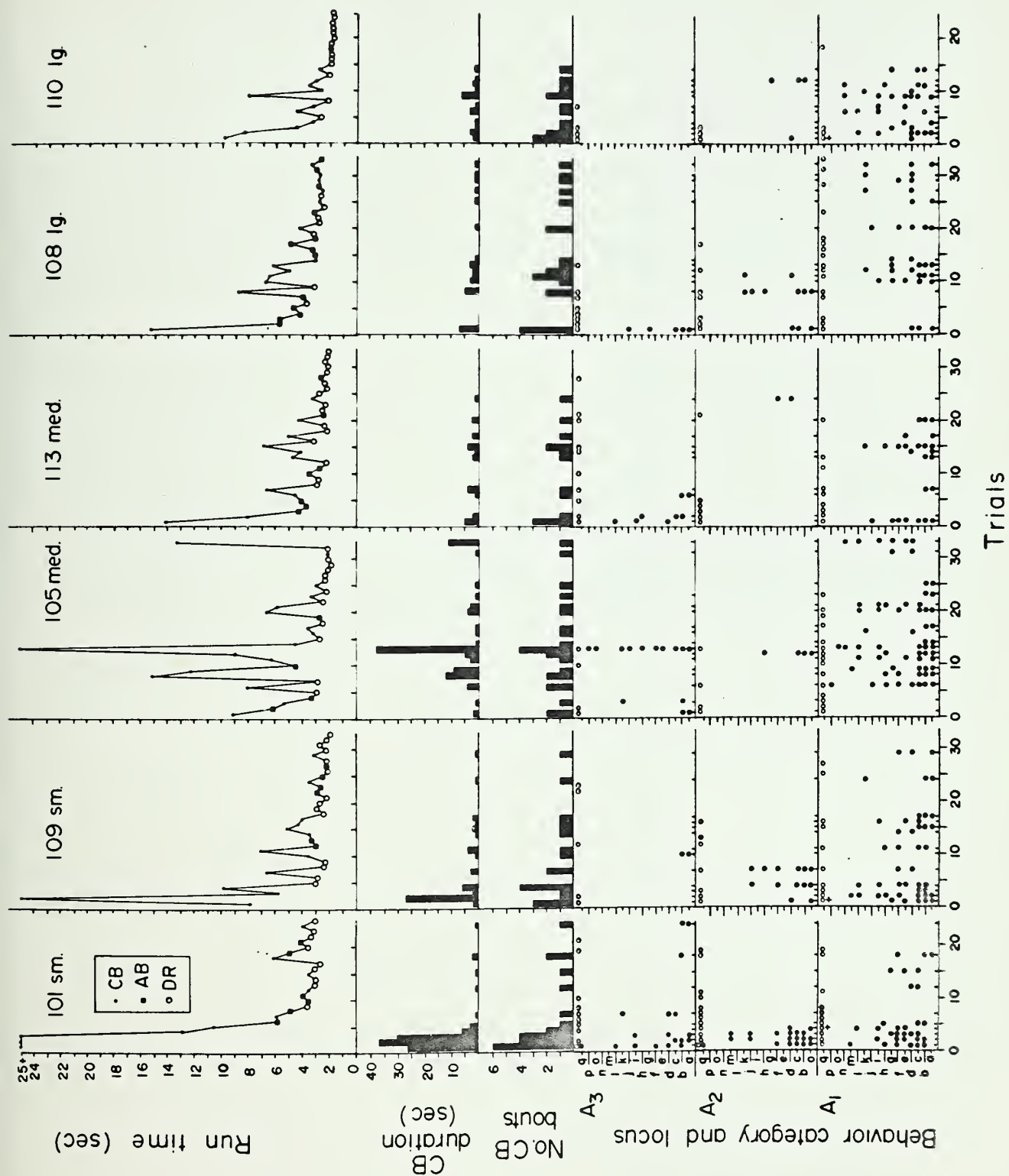
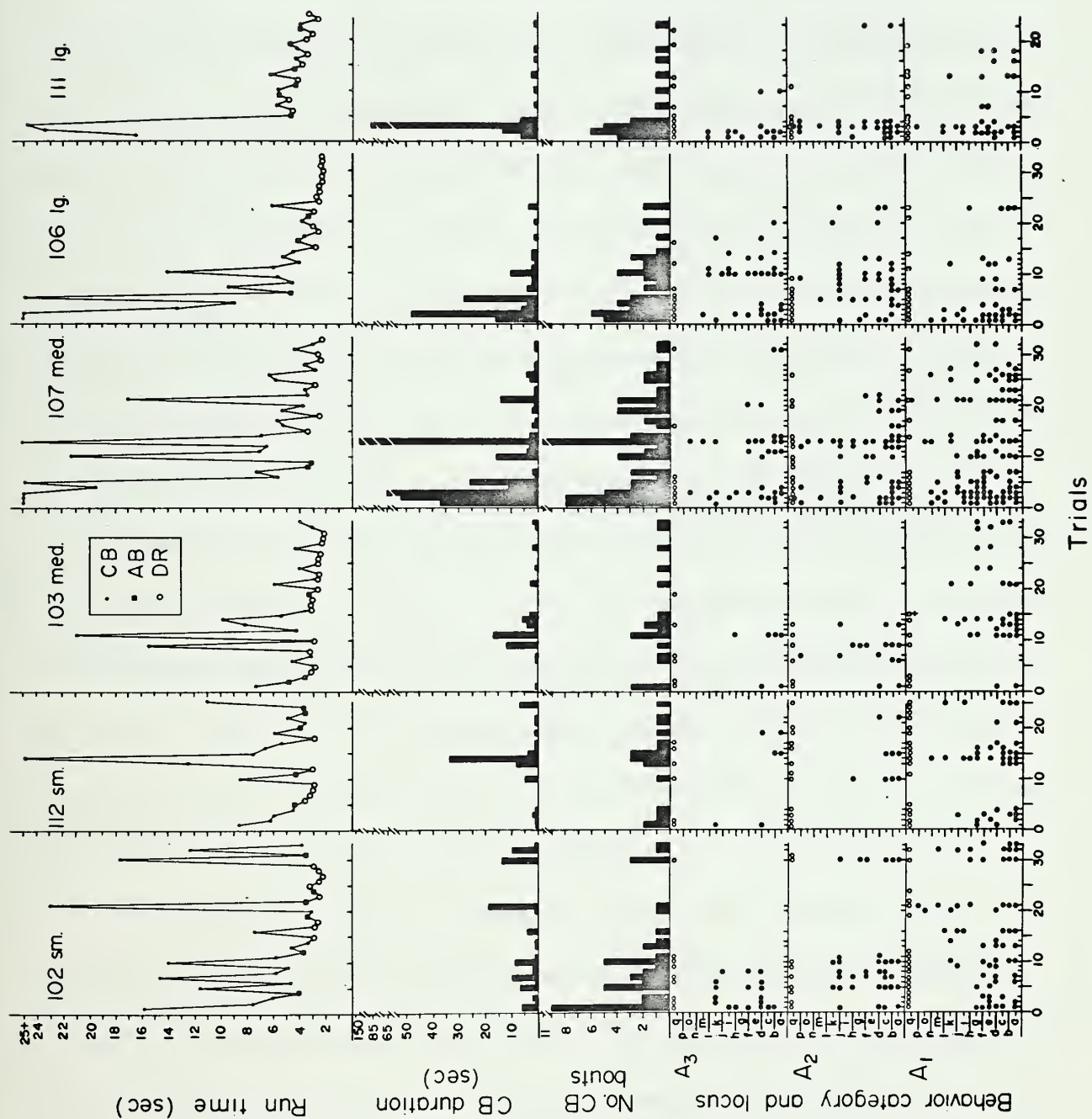


Fig. 3. Behavior in Acquisition for Gp T.



into A_1 , and ended when the subject's rear legs began moving forward again. A retrace was scored as a single bout regardless of the number of separate stops and starts which occurred during the retrace. The bottom three panels show for each of the three segments of the alleyway all of the categories of competing behavior which occurred on each CB trial (filled dots). Each CB trial is marked with a short vertical line on the abscissas of each of these last three panels. The order of the categories on the ordinate from bottom to top (a-q) is roughly in order of decreasing frequency for both groups combined, throughout the experiment. Crosses near the top of the three panels represent each occurrence of categories not listed, e.g., defecation. Unfilled dots at the top of these last three panels mark the occurrence of accessory behavior in each segment, but not broken down into categories since, as will be shown later, only three categories occurred with notable frequency. The detailed description in the lower panels of these and subsequent figures focuses on competing behavior since changes in accessory behavior throughout training closely paralleled those seen for competing behavior.

It can be seen in the top panels of Figs. 2 and 3 that run time decreased across trials for each subject. The decrease was relatively orderly for some subjects (e.g., rats 101, 109, 113, 108, 110, 106, 111), but for others periods of very long run times occurred after early acquisition (see rats 105, 102, 112, 103, 107). For all subjects except 105, 102, 112, and 103, the first few acquisition trials were the longest of all.

Competing behavior invariably occurred on these long early trials. As succeeding panels of Figs. 2 and 3 show, this competing behavior on the very first trials usually was of long duration, occurred in multiple bouts, involved many categories, and was seen throughout the alleyway; this was particularly the case for the thirsty subjects. Accessory behavior, typically prolonged floor-sniffing, also occurred throughout the alleyway on the long early acquisition trials for all subjects. The large decrease in overall run time in acquisition reflects a corresponding decrease in the "amount" of noninstrumental behavior, which was qualitatively similar for the hungry and thirsty subjects. The behavioral changes underlying the decrease in the amount of competing and accessory behavior are illustrated for each individual subject in Figs. 2 and 3, and are summarized quantitatively for the two groups across the first 25 trials, in blocks of 5, in Table 2. (Note that in the group averages in Table 2 there is an increase in run time and a corresponding increase in measures of competing and accessory behavior on trials 11-15 due to rats 105, 113, 108, 112, 103, and 107 showing longer trials at that point, and a similar increase in some measures for Gp T on trials 21-25 due largely to rats 102 and 107.) First, the frequency of occurrence of CB trials decreased across acquisition. This can be seen for individual subjects in several ways, e. g., the decrease in the frequency of marks along the abscissa of any of the bottom three panels of the figures, or in the frequency of entries in panels 2 and 3, and can be seen overall for the two groups in

Table 2

Summary of Behavior Changes in Acquisition
(Trials 1-25) for Both Groups

Subjects		Trials						
		1-5	6-10	11-15	16-20	21-25	\bar{X}	
<hr/>								
Panel #								
1	\bar{X} Run Time/Trial							
	Gp H	11.01	5.05	5.41	3.35	2.81	5.52	
	Gp T	21.66	6.70	11.92	3.98	4.94	9.84	
2	Frequency of CB Trials/Block							(CB Run Time)
	Gp H	.60	.47	.63	.30	.23	.45	(8.60)
	Gp T	.77	.60	.67	.43	.40	.57	(13.83)
3	Frequency of Trials with AB/Block							(AB Run Time)
	Gp H	.87	.47	.57	.37	.23	.50	(3.52)
	Gp T	.93	.63	.63	.37	.37	.59	(3.90)
4	Frequency of DR Trials/Block							(DR Time)
	Gp H	.10	.33	.20	.50	.57	.34	(2.58)
	Gp T	.07	.27	.20	.40	.40	.27	(3.03)
5	Time in CB (Sec.)/CB Trial							
	Gp H	6.82	3.33	3.40	1.53	.90	3.20	
	Gp T	16.35	4.10	10.83	1.09	5.41	7.56	
6	# Bouts of CB/CB Trial							
	Gp H	2.48	1.32	1.35	1.40	1.00	1.51	
	Gp T	3.81	1.75	2.14	1.30	1.33	2.10	

Table 2 (continued)

Subjects	Trials					\bar{X}	
	1-5	6-10	11-15	16-20	21-25		
Panel #							
7	# Categories of CB/CB Trial						
	Gp H	5.30	4.21	3.67	3.37	2.40	3.79
	Gp T	6.64	4.27	4.50	2.87	4.42	4.54
8	Proportion of CB Trials on Which CB Occurred in Each Alleyway Segment						
	Gp H						
	A ₃	.60	.33	.04	.20	.20	.27
	A ₂	.43	.17	.14	0	.20	.19
	A ₁	.75	.58	.95	1.00	.50	.76
	Gp T						
	A ₃	.77	.25	.34	.32	0	.34
	A ₂	.72	.71	.39	.20	.47	.50
	A ₁	.97	.47	.82	.58	.74	.72
9	Proportion of CB and AB Trials on Which AB Occurred in Each Alleyway Segment						
	Gp H						
	A ₃	.73	.67	.25	.25	.53	.49
	A ₂	.81	.56	.40	.39	.20	.47
	A ₁	.90	.74	.80	1.00	.47	.78
	Gp T						
	A ₃	.78	.64	.33	.47	.20	.48
	A ₂	.88	.68	.39	.22	.25	.48
	A ₁	1.00	.48	.79	.72	.80	.76

the second panel of Table 2. The frequency of occurrence of accessory behavior also decreased in acquisition, as the bottom three panels of the figures and the third panel of Table 2 show. Corresponding to the decrease in the frequency of trials with competing and accessory behavior, the frequency of DR trials increased in training (Figs. 2 and 3; Table 2, panel 4).

Not only the frequency, but also the length of CB trials decreased in acquisition, as the top panel of Figs. 2 and 3 shows. This was mainly due to a decrease in the time spent in competing behavior per CB trial, shown in the second panel of the figures and panel 5 of Table 2. The length of AB trials also decreased in acquisition (Figs. 2 and 3, top panel). This decrease similarly reflected a decrease in the time spent in accessory behavior, yielding more unimpeded running per AB trial, though this is not shown. The decrease in the time spent in accessory behavior also accounted for a small part of the decrease in the overall run time on CB trials showing accessory as well as competing behavior.

As the duration of competing behavior decreased, the number of bouts of competing behavior per CB trial decreased (Figs. 2 and 3, panel 3; Table 2, panel 6), the number of categories per CB trial decreased (Figs. 2 and 3, last three panels; Table 2, panel 7), and competing behavior became concentrated in the first alleyway segment, farthest from the goal-box, especially for Gp H (Figs. 2 and 3, last three panels; Table 2, panel 8). Comparable changes occurred in accessory behavior. However, though accessory behavior did become more concentrated in A_1 , it

continued to occur more frequently in A_2 and A_3 farther into acquisition than competing behavior for both groups (Figs. 2 and 3, last three panels; Table 2, panel 9).

Thus, most of the decrease in overall run time in acquisition is clearly attributable to the decrease in the number of trials showing competing and accessory behavior, and the decrease in the time spent in competing and accessory behavior given such a trial. However, decreases in competing and accessory behavior alone did not account for all of the decrease in overall run time in acquisition. Figures 2 and 3 show that there were also consistent decreases in DR time across trials for every subject of both groups. With very little variation between subjects, the longest DR trial was about one and a half times as long as the shortest in acquisition (trials 1-25 for the early-shift subjects, and 1-33 for the others) and about twice as long as the shortest for the entire experiment. This is shown quantitatively for individual subjects in Table 3. For the individuals of both groups, AB trials were longer than DR trials at any point in training, as Figs. 2 and 3 show, but showed the same ratio of longest to shortest (1.5:1 in acquisition and 1.9:1 throughout), with more variation between subjects than for DR trials. CB trials were the longest of all at any point in training, and for each subject showed a vastly larger ratio of longest to shortest, averaging around 10:1 in acquisition and throughout for Gp H and 20:1 for Gp T, with large differences between subjects.

Table 3

Range of DR Times in Acquisition and
Throughout Training

Subjects	Longest DR Trial (Sec.)		Shortest DR Trial (Sec.)		Ratio Longest/Shortest	
	Acq.	(Throughout) ^a	Acq.	(Throughout)	Acq.	(Throughout)
<u>Gp H</u>						
101	3.60		2.63	(1.70)	1.4	(2.1)
109	3.04		1.89	(1.52)	1.6	(2.0)
105	2.86		1.77	(1.49)	1.6	(1.9)
113	3.14		2.05	(1.72)	1.5	(1.8)
108	3.68	(3.76)	2.43	(2.06)	1.5	(1.8)
110	2.69		1.75	(1.58)	1.5	(1.7)
\bar{X}	3.17	(3.18)	2.09	(1.68)	1.5	(1.9)
<u>Gp T</u>						
102	3.23	(4.00)	2.20	(1.98)	1.5	(2.0)
112	3.62		2.90	(1.92)	1.3	(1.9)
103	3.20		2.06	(2.02)	1.6	(1.6)
107	3.35		2.32	(1.88)	1.4	(1.8)
106	2.97	(3.16)	2.30	(1.80)	1.3	(1.8)
111	4.85		2.74	(2.26)	1.8	(2.1)
\bar{X}	3.54	(3.70)	2.42	(1.98)	1.5	(1.9)

^aNo entry in this column indicates that the longest DR trial in acquisition was also the longest throughout training.

Effects of amount of reward, and
deprivation state and associated
reward, on acquisition

Despite the small number of subjects at each reward magnitude in acquisition and the considerable quantitative differences between subjects at the same magnitude, subjects receiving large reward generally ran faster in acquisition than those receiving medium or small. This is shown quantitatively for a representative block of acquisition trials, 21-25, in the first column of Table 4. Correspondingly, the large-reward subjects in both groups showed slightly fewer trials with competing and accessory behavior and more DR trials across the first 25 trials, as is shown in the next three columns of Table 4. Also, for Gp H, but not Gp T, the total time spent in competing behavior during acquisition varied inversely with amount of reward. Within Gp H, excluding rat 108, the point before a change in conditions at which stable DR runs began to predominate was reached first by the subject receiving large reward, next by those receiving medium, and last, if at all, by those receiving small, as Table 4 shows. (Note also in Fig. 2 that even though rat 108 (lg.) did not show stable DR runs, his overall run time did stabilize rather early, at trial 24.) It was not possible to determine this relationship in any detail for Gp T since only one subject, rat 106, showed stable DR performance before a change in conditions. However, it is consistent with the results for Gp H that this subject was receiving large reward. Finally, it is also seen in Table 4 that, for those rats who showed a stable DR asymptote

Table 4

Effects of Amount of Reward on Acquisition

Subjects	\bar{X} Run Time (Sec.), Trials 21-25	# CB Trials ^a	# Trials with AB ^a	# DR Trials ^a	Time in CB (Sec.) ^a	First Trial Stable DR Runs	\bar{X} Run Time (Sec.), Trials 50-54
<u>Gp H</u>							
101 sm	3.48	10	13	9	106.52	-	1.95 ^b
109 sm	2.75	12	13	8	52.17	30	1.81
109 X sm	3.12	11	13	8.5	79.35	-	- ^b
105 med	3.33	15	15	6	86.64	26	1.87 ^c
113 med	2.62	10	14	9	22.93	25	1.94
113 X med	2.98	12.5	14.5	7.5	54.79	25.5	1.91
108 lg	2.81	9	15	6	27.74	-	-
110 lg	1.85	11	5	13	19.82	15	-
110 X lg	2.33	10	10	9.5	23.78	-	-
<u>Gp T</u>							
102 sm	7.02	15	16	5	64.77	-	-
112 sm	5.40	14	18	6	64.33	-	-
112 X sm	6.21	14.5	17	6.5	64.55	-	-
103 med	3.55	11	11	11	48.12	-	-
107 med	6.57	20	18	3	421.00	-	-
107 X med	5.06	15.5	14.5	7	234.56	-	-
106 lg	3.61	16	14	6	130.53	24	1.93
111 lg	3.48	10	12	9	115.76	-	-
111 X lg	3.55	13	13	7.5	123.15	-	-

^aTrials 1-25.^bRat 101 receiving large reward, after upshift.^cOne fast AB trial (#51) occurred.

late in training (trials 50-54), run time varied little as a function of reward magnitude. Thus, reward magnitude affected the rate of the acquisition process (mainly the rate of the dropping out of competing and accessory behavior, but also the rate of decrease in DR time), but did not greatly affect the final asymptotic level of performance.

It is clear from the data presented in Figs. 2 and 3 that while the process of acquisition was qualitatively the same for Gp H and Gp T, it was slower for the thirsty subjects. Overall run time was longer throughout (see Table 4, first column), and every behavioral change underlying the decrease in overall run time in acquisition was slower for Gp T (Table 2, panels 2-9) with the single exception that accessory behavior continued to occur in A_2 and A_3 about equally often for the two groups through the first 25 trials. Thus, the thirsty subjects showed more trials with competing and accessory behavior, fewer DR trials, and their CB, AB, and DR trials were all longer than those of the hungry subjects in acquisition. They showed more time in competing behavior, more bouts of competing behavior, and more categories of competing behavior per CB trial, and a higher frequency of competing behavior outside A_1 at every stage of acquisition than the hungry subjects. Finally, in contrast to the hungry subjects, only one thirsty subject (rat 106) showed stable DR performance before a change in conditions.

Shifts in amount of reward

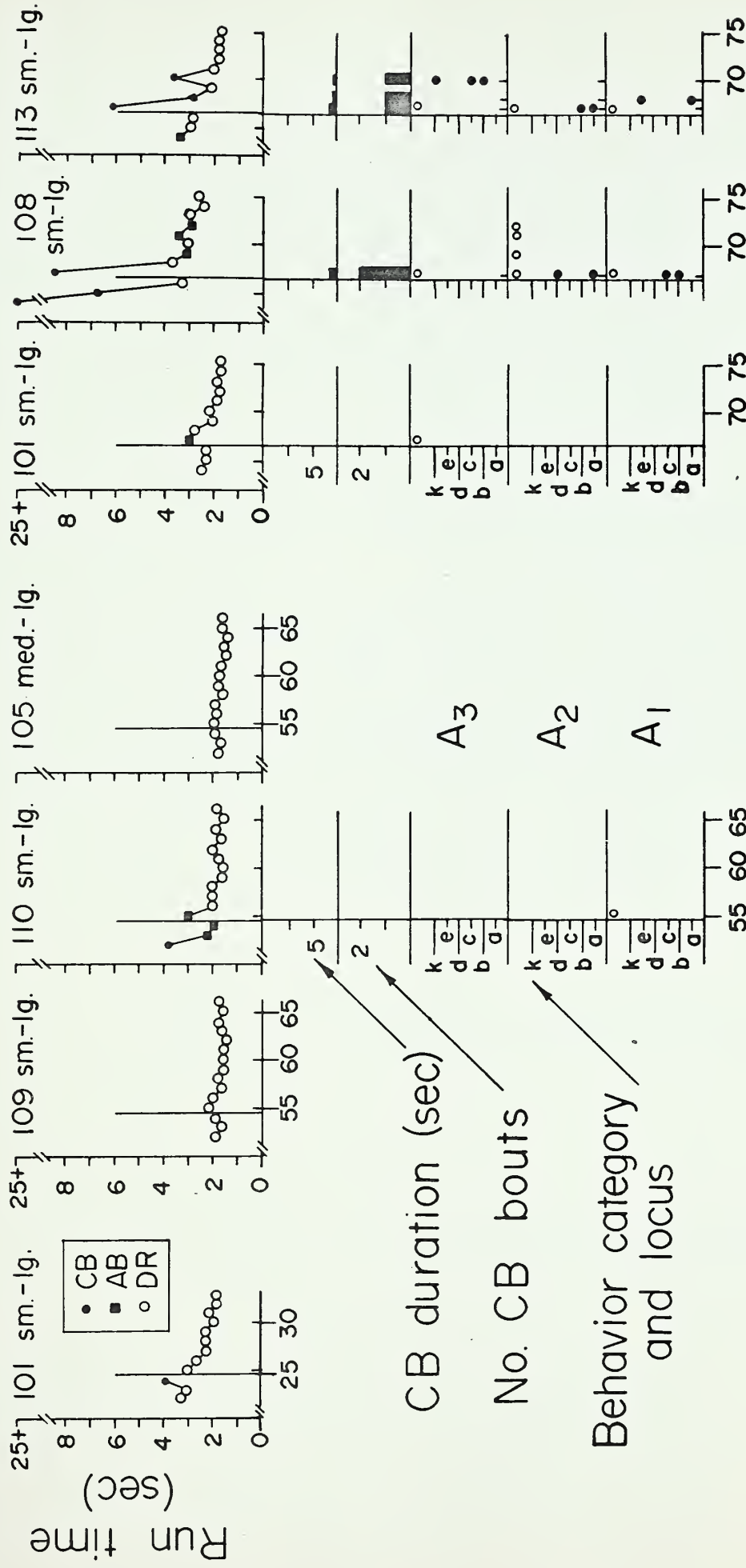
Figure 4 shows the performance of individual subjects in Gp H following reward magnitude upshifts at early, middle, and late stages of training, plotted as in Figs. 2 and 3. Figure 5 shows comparable data for Gp T. Performance on the last three trials preceding the shift (marked by a long vertical line from the abscissa) is also shown for each subject in both figures. Only those categories of competing behavior which occurred for a group during upshifts are listed on the ordinate of the bottom three panels in these figures. It can be seen clearly in the individual data for Gp H that upshifts in amount of food at any stage of training were followed by fast, stable DR runs. Following a preceding downshift, however, it sometimes took several trials before the upshift resulted in stable DR runs (e.g., rats 108 and 113, late upshift). The apparent magnitude of the effect depended on the preshift baseline of behavior. The upshift effect appeared large whenever baseline performance consisted of relatively long and variable runs, especially involving competing and accessory behavior, such as early in training (rat 101) and at middle or late stages of training following a preceding downshift (rats 110, 108, 113). The effect appeared very much smaller when preshift runs were already stable, asymptotic DR's, as for rats 109 and 105 at the middle shift. The effects of upshifts in amount of water (Fig. 5) similarly involved decreases in amount of competing and accessory behavior and decreases in DR time. Yet, while run times were faster and less variable for most subjects of

Fig. 4. Behavior Following Upshifts in Amount of Reward for Gp H.

Early

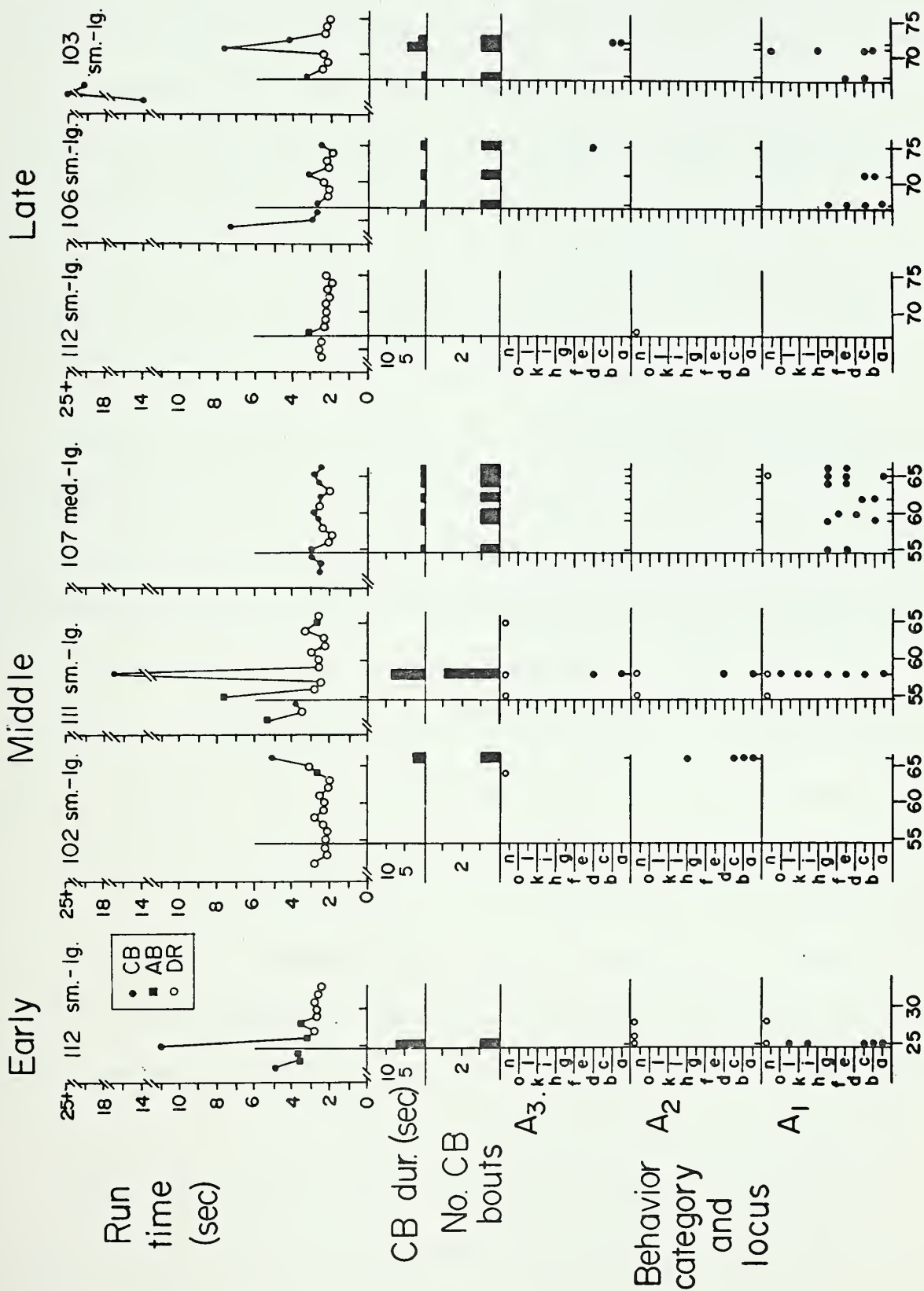
Middle

Late



Trials

Fig. 5. Behavior Following Upshifts in Amount of Reward for Gp T.



Trials

Gp T following upshifts, they were not as stable as for Gp H. There were usually fewer DR runs postshift, more residual competing and accessory behavior, and greater trial-to-trial variability overall than with upshifts in amount of food, as comparison of Figs. 4 and 5 shows. Rats 102 and 107 showed no obvious improvement in performance after an upshift, and only rat 112 showed postshift performance as stable as that of the hungry subjects. The apparent magnitude of the effect for Gp T, as for Gp H, generally depended on the rate and stability of preshift run times.

Figure 6 illustrates performance for the individuals of Gp H following downshifts in amount of food, plotted as in Figs. 4 and 5. Note that performance following the early downshift for rat 110 is plotted through trial 54, while for the other early-shift subjects in Figs. 4-7 performance is shown only through trial 33. The latter subjects either clearly showed a disruption of running by the extra stimulus at trial 34, and their data are therefore presented later (rats 101 and 111), or they showed almost exclusively fast DR runs postshift, and are therefore not shown (rat 112). It is seen in Fig. 6 that downshifts in amount of food at early and middle stages of training resulted in a large-scale return of competing and accessory behavior and a lengthening of DR times. At the late stage of training, the subject without previous experience with small reward (rat 105) showed a comparably large effect. However, the subjects with previous experience with small reward showed very small effects, involving a slight lengthening of DR times (rat 110) or an occasional fast CB trial (rat 109). The effects

Fig. 6. Behavior Following Downshifts in Amount of Reward for Gp H.

Early

Middle

Late

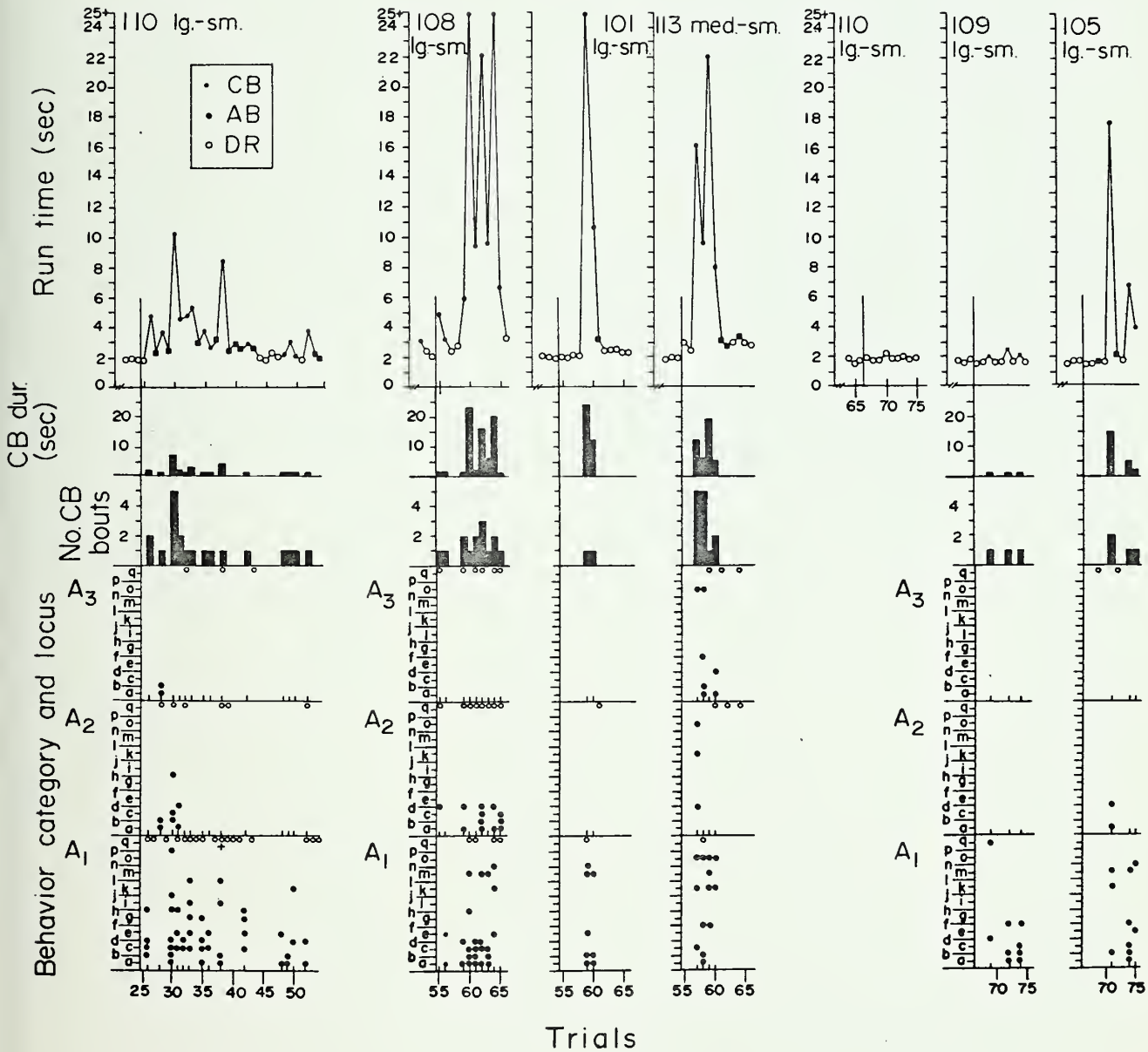


Fig. 7. Behavior Following Downshifts in Amount of Reward for Gp T.

Early

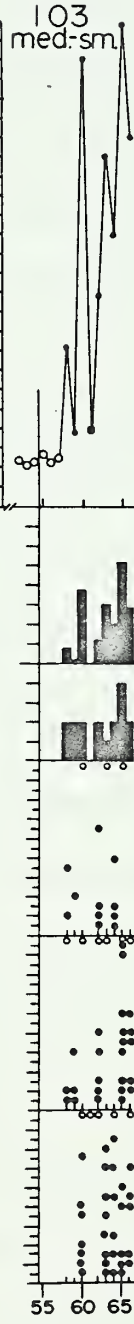
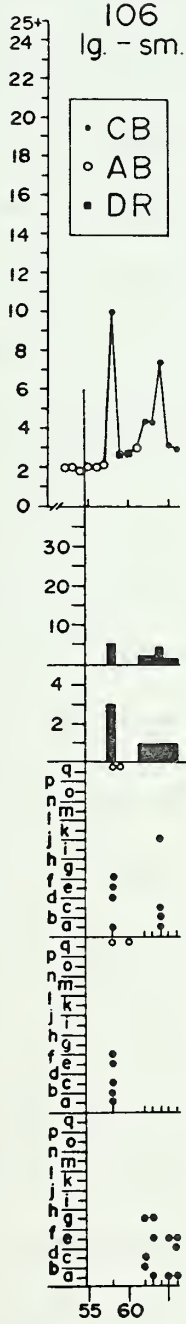
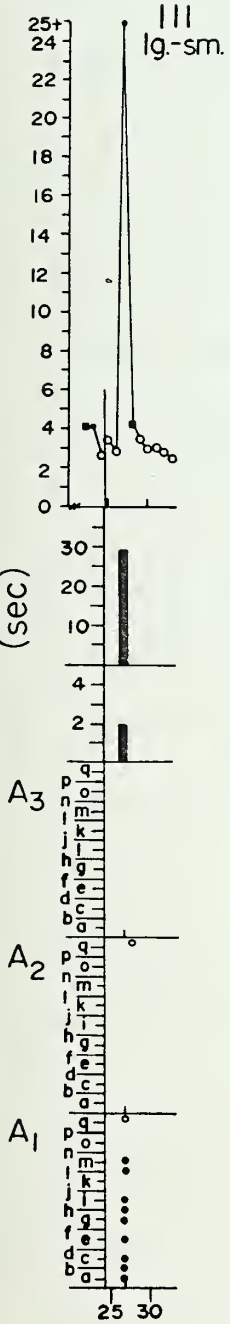
Middle

Late

Run time (sec)

No. CB bouts

Behavior category and locus



Trials

of downshifts with water, shown in Fig. 7, were similar but usually weaker. Thus, the early downshift subject of Gp T (rat 111) showed no clear decremental effect (only one long CB trial postshift), and only rats 103 and 106 at the middle downshift showed large effects comparable in magnitude to those with food reward reductions. There was a similar effect of previous experience with small reward on the late downshift with water, with experienced subjects showing no decremental effect (rat 102), or only a slight lengthening of DR times (rat 111). However, the decremental effect even for the thirsty subject not previously receiving small reward (rat 107) was very slight, less than that for the corresponding hungry subject (rat 105).

Thus, as in acquisition, large changes in run time with food or water reward magnitude shifts were mediated mainly through changes in the amount of competing and accessory behavior, though DR time also changed, within a much narrower range. When competing and accessory behavior had dropped out and run time was relatively stable at middle or late stages of training, upshift effects still occurred, but appeared very slight in terms of change from baseline; large downshift effects still occurred, especially for subjects who had not previously experienced small reward. Though there was some overlap among individuals, the hungry subjects as a group showed greater disruption of running with downshifts and more stable performance following upshifts than did the thirsty subjects.

In general, behavior on long trials following reward magnitude

downshifts was typical of that earlier in acquisition. It can be seen in Figs. 6 and 7 that, when downshifts engendered very long run times at any stage of training, long-duration competing behavior occurred in multiple bouts, or involved long retraces (m), comprised multiple categories, and was not always confined to early parts of the alleyway (see rats 110, 108, 113, 105, 106, 103). Accessory behavior also often occurred throughout the alleyway on such long postdownshift trials. When run times were shorter, as when the initial effect was less disruptive (rats 109 late and 112 middle), or after a number of trials with the reduced reward (rats 110 early, 113 middle, 101 middle, and 105 late), the trials resembled those later in acquisition. AB and DR trials, often longer than preshift, were seen in addition to shorter CB trials. The CB trials which did occur generally involved a single bout with few categories and, especially for Gp H, seldom outside of A_1 .

Some individual rats showed categories of competing behavior following downshifts which they had not shown earlier in training. Rats 101, 108, and 103 showed turns (n), sometimes with retraces (m), for 1-3 trials; rats 113 and 103 showed freezing (o) for 1-4 trials; rat 110 showed rearing and sniffing the top (p, j) for one trial; and rats 109 and 103 showed rearing in the center of the alleyway (q) for one trial. New categories of accessory behavior also occurred following downshifts, viz., sniffing the wall on one trial for rat 111 and accessory hesitating on six trials for rat 110. Therefore, the return of competing and accessory behavior with

downshifts was not a simple within-subjects "regression" to earlier alleyway behavior patterns. However, in some cases these "new" behaviors for a given subject had been shown earlier in acquisition by that subject, but occurred either in SB before a trial or during a retrace, and were thus not scored. At any rate, all of these categories were shown in the alleyway earlier in acquisition by some subjects of both groups (Figs. 2 and 3). Thus while downshifts in reward magnitude did occasion the first occurrence of a few categories of competing and accessory behavior for several subjects, there were no categories specific to downshifts. Also, there was no large systematic effect of downshifts on the overall relative frequency of most categories for the two groups; behaviors which were the most common in the early stages of acquisition were also the most common after a downshift, as is suggested by the predominance of points in the lower part of the bottom three panels in Figs. 6 and 7.

"Extra stimulus"

Immediately following the session terminating with trial 33, portions of the floor and ceiling of the experimental room were sprayed with insecticide. Approximately 20 hours intervened between the spraying and the beginning of the next session at trial 34, at which time the odor of the spray was barely detectable to the human observer, and was at any rate quickly adapted to. Nonetheless, several of the subjects showed some disruption of running for several days following the inadvertent introduction

of the extra stimulus. For these subjects there was an increase in the trial-to-trial variability of run time, reflecting the occurrence of long CB or AB trials, and in some cases longer DR trials. Figure 8 shows performance under the influence of the extra stimulus, and on the preceding session, for those subjects who showed more than one long CB trial, or a clear increase in the variability of overall run time, or both. It is seen that more subjects in Gp T than in Gp H showed such an effect, and that overall run time was longer, variability in run time from trial to trial was greater, and every measure of amount of competing and accessory behavior was greater for Gp T than Gp H in the presence of the extra stimulus.

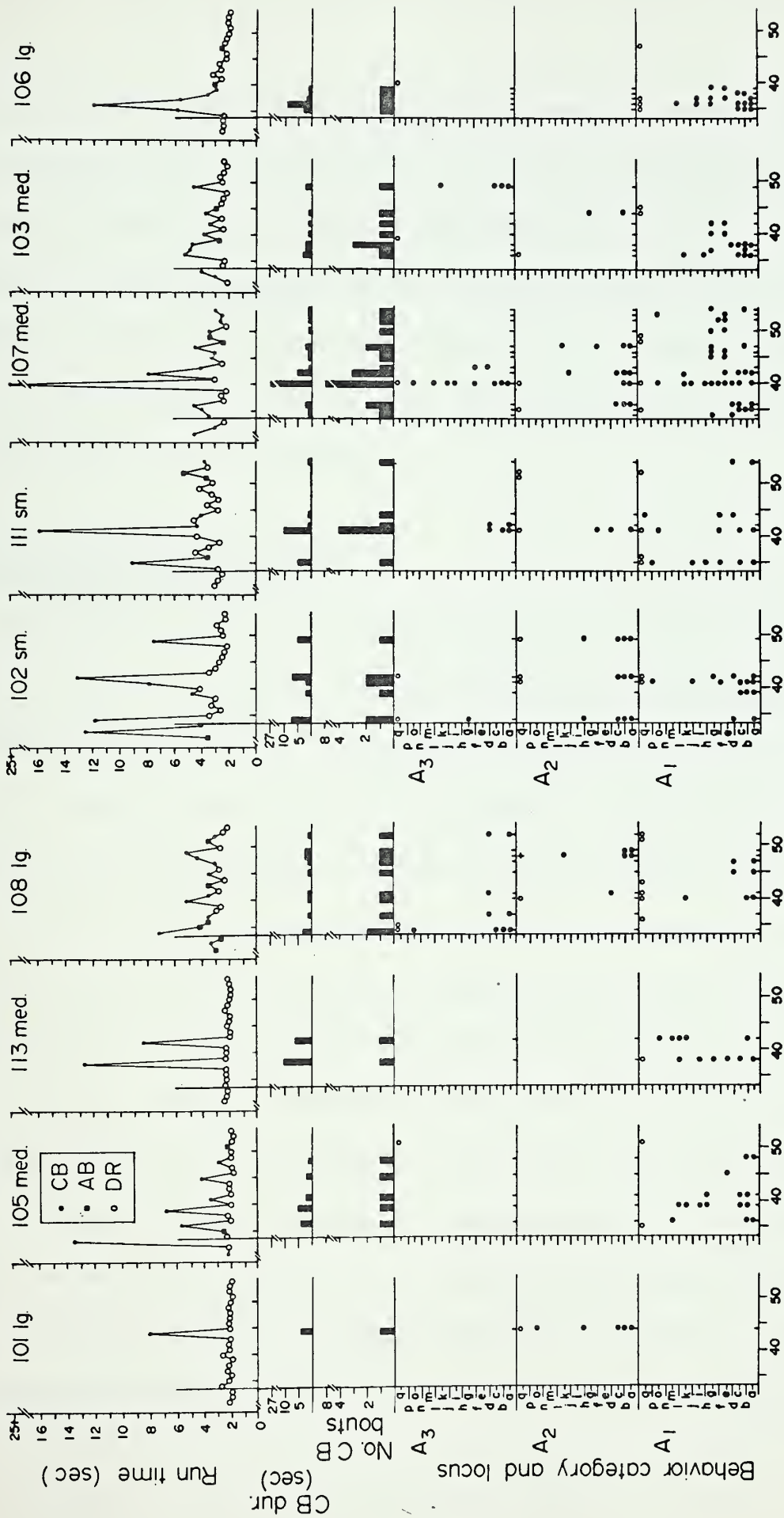
For both groups the magnitude of the disruptive effect generally decreased across trials and, as with reward magnitude downshifts, the behavioral changes underlying the decrease in overall run time paralleled those seen in acquisition. Thus there was a decrease in the frequency of trials with competing behavior and decreases in the time spent in competing behavior per CB trial, the number of bouts and categories per trial, and the frequency of occurrence of competing behavior outside A_1 , and parallel decreases in accessory behavior (see especially rats 105, 103, 107, and 106 in Fig. 8).

As with downshifts, some "new" behaviors appeared for some subjects following the introduction of the insecticide stimulus (freezing [o] for rats 101, 108, and 111 on one trial, and accessory facing-right or

Fig. 8. Behavior in the Presence of the Extra Stimulus
for Gp H and Gp T.

Group H

Group T



Trials

-left for rat 103 on one trial). But again, these behaviors were sometimes shown by these subjects earlier in acquisition in SB before a run, or during a retrace, and were at any rate characteristic of the subjects of both groups earlier in training, and not responses unique to the stimulus change. Also, for both groups the relative frequency of most of the categories of competing and accessory behavior was not systematically affected by the insecticide stimulus.

Locus of competing and accessory behavior and the goal gradient

It was shown earlier that in acquisition competing and accessory behavior dropped out of the latter parts of the alleyway and became progressively concentrated in A_1 , especially for Gp H (Figs. 2 and 3 and Table 2). Data presented in Figs. 4-8 suggest that these behaviors continued to occur most frequently in A_1 with reward magnitude shifts or the extra stimulus. Table 5 summarizes for each subject and each group the proportion of the CB and AB trials throughout the experiment on which competing and accessory behavior occurred in each of the three segments of the alleyway. For each subject competing behavior occurred far more frequently overall in the first segment than in either of the other two segments. While the relative frequency of competing behavior in A_1 was about the same for Gp H and Gp T, the thirsty subjects showed somewhat higher relative frequencies of competing behavior in A_2 and A_3 . Accessory behavior also occurred most often in A_1 for all but rats 101 and 107,

Table 5

Proportion of Total CB and AB Trials on Which Competing
and Accessory Behavior Occurred in Each
Alleyway Segment in Experiment I

Subjects	A ₁		A ₂		A ₃	
	CB	(AB)	CB	(AB)	CB	(AB)
<u>Gp H</u>						
101	.69	(.71)	.46	(.82)	.46	(.65)
109	.94	(.75)	.18	(.44)	.06	(.31)
105	.92	(.89)	.08	(.21)	.12	(.37)
113	.74	(.52)	.16	(.43)	.37	(.61)
108	.72	(.71)	.38	(.53)	.16	(.45)
110	.92	(.88)	.20	(.36)	.04	(.28)
\bar{X}	.82	(.74)	.27	(.47)	.20	(.45)
<u>Gp T</u>						
102	.83	(.83)	.46	(.50)	.29	(.50)
112	.76	(.86)	.24	(.68)	.18	(.27)
103	.72	(.61)	.34	(.57)	.25	(.43)
107	.87	(.65)	.37	(.69)	.25	(.38)
106	.67	(.68)	.47	(.45)	.43	(.55)
111	.82	(.77)	.41	(.55)	.41	(.59)
\bar{X}	.78	(.73)	.38	(.57)	.30	(.45)

but for every subject accessory behavior was more evenly spread out in the alleyway than was competing behavior.

Although time-consuming competing and accessory behaviors did occur more often throughout the experiment in A_1 than in latter parts of the alleyway, the goal gradient was not entirely due to the early-segment bias of these behaviors. Table 6 shows for each subject and each group the mean run time in each alleyway segment across all trials, and separately for DR trials, throughout training. Also summarized is the proportion of trials showing a positive goal gradient, as indicated by a longer run time in A_1 than in A_2 . Each subject of Gp H showed a much longer mean overall run time in A_1 than in A_2 and showed this pattern on a large proportion of trials. Three of the hungry subjects showed a "downturn" in the overall gradient, i.e., longer run time in A_3 than in A_2 , but not longer than in A_1 (rats 101, 105, and 113). Each subject of Gp H also showed a positive goal gradient on the great majority of his DR trials, although the magnitude of the A_1 - A_2 difference was greatly reduced by the elimination of competing and accessory behavior. A downturn in the DR gradient occurred for every hungry subject, and for rat 113 A_3 time was the longest of all.

A positive goal gradient was also seen on the average for Gp T, both across all trials and on DR trials alone. As for Gp H, the magnitude of the A_1 - A_2 difference was reduced by the elimination of competing and accessory behavior. Both overall and on DR trials alone the goal gradient

Table 6
Mean Run Time (Sec.) per Alleyway Segment
in Experiment I

Subjects	A ₁		A ₂		A ₃		Proportion A ₁ > A ₂	
	Overall	(DR)	Overall	(DR)	Overall	(DR)	Overall	(DR)
<u>Gp H</u>								
101	1.97	(.80)	.80	(.69)	1.16	(.79)	.81	(.89)
109	1.62	(.75)	.77	(.59)	.73	(.65)	.91	(.96)
105	2.33	(.70)	.71	(.55)	1.08	(.69)	.99	(.98)
113	1.80	(.77)	.91	(.69)	1.13	(.79)	.73	(.74)
108	2.41	(1.04)	1.35	(.86)	1.22	(.92)	.83	(.96)
110	1.45	(.72)	.77	(.58)	.75	(.64)	.96	(.97)
\bar{X}	1.93	(.80)	.89	(.66)	1.01	(.75)	.87	(.92)
<u>Gp T</u>								
102	1.89	(.77)	1.66	(.83)	1.18	(.92)	.47	(.32)
112	1.95	(.89)	1.06	(.78)	.93	(.81)	.91	(.94)
103	2.34	(.88)	1.67	(.78)	1.37	(.84)	.77	(.81)
107	4.80	(.87)	3.06	(.80)	1.81	(.81)	.77	(.84)
106	1.66	(.77)	1.62	(.74)	1.97	(.88)	.61	(.66)
111	2.17	(.98)	2.54	(1.08)	1.46	(1.11)	.37	(.20)
\bar{X}	2.47	(.86)	1.94	(.84)	1.45	(.90)	.65	(.63)

for Gp T was seen on fewer trials and was smaller on the average than for Gp H. There were wide individual differences in the goal gradient among the subjects of Gp T. Some thirsty rats (112, 103, 107) showed large overall and DR gradients, comparable to those seen for the hungry rats. However, rat 106 showed only very small positive gradients in both measures, rat 111 failed to show a positive gradient on the average with either measure, and rat 102 did not show the pattern on DR trials. One thirsty subject (rat 106) showed a downturn in the gradient of overall run time, and all showed a downturn in the DR gradient. Further, three subjects of Gp T showed the longest times of all on DR trials in A_3 (rats 102, 106, and 111).

Gait

It was of interest to determine whether variations in DR time corresponded exactly to variations in gait. This could be done only in a general way since only gross distinctions, between galloping and other gaits ("runs"), could be made reliably. Table 7 shows for each subject the range of run times on DR trials showing each type of gait. Only DR trials showing a given gait for more than two-thirds the length of the alleyway were included. It is seen that for each subject who showed both gallops and "runs" DR times were generally shorter on gallop trials than on "run" trials. (Note also that Gp H galloped more than Gp T.) However, for all except rat 107 the fastest "run" was somewhat faster than the slowest

Table 7

Range of Run Times (Sec.) on DR Trials
Showing "Run" and Gallop Gaits

Subjects	# Trials	"Run"		# Trials	Gallop	
		Longest DR	Shortest DR		Longest DR	Shortest DR
<u>Gp H</u>						
101	(39)	3.60	1.83	(5)	2.13	1.70
109	(29)	3.04	1.72	(18)	1.84	1.52
105	(10)	2.86	1.79	(29)	2.16	1.49
113	(41)	3.14	1.85	(1)	1.89	1.89
108	(23)	3.76	2.06	-	-	-
110	(1)	2.01	2.01	(30)	2.13	1.58
<u>Gp T</u>						
102	(20)	4.04	2.11	(17)	2.77	1.98
112	(47)	3.62	1.92	(1)	2.02	2.02
103	(34)	3.20	2.02	-	-	-
107	(17)	3.35	2.12	(2)	2.01	1.88
106	(30)	3.16	1.93	(5)	2.13	1.80
111	(46)	4.85	2.32	-	-	-

gallop. While gait changes may account then for much of the variation in DR time, run times on trials showing different gaits still overlapped extensively. There was thus no precise correspondence between DR run time and gait.

Range and frequency of competing
and accessory behaviors

Table 8 lists the categories of competing behavior seen in the alley-way and summarizes for each subject and each group the proportion of CB trials throughout training on which a given category was observed. The categories of gross movement and receptor-orienting competing behavior are listed in the approximate order of frequency throughout training for both groups combined. Categories which occurred only after the acquisition phase of training was completed are separately marked. For both groups, by far the most common categories of gross movement competing behavior throughout were stopping and hesitating, and the most common receptor-orienting behaviors were sniffing the floor and walls. The rank-order of the other categories was also similar for both groups. This was the case in every stage of training. Next it may be noted that the subjects of Gp H and Gp T did not differ in the range of categories of competing behavior shown in acquisition or throughout the rest of the experiment. There were no categories shown exclusively by one group, and thus no evidence for qualitative differences in the categories of competing behavior shown by the hungry and thirsty subjects.

Table 8

Proportion of CB Trials on Which Each CB Category
Occurred in Experiment I

Subjects	Categories of Competing Behavior						
	# CB Trials	Gross Movement					
		ST	H	E	T 1/2 ret	T 1/4	F
<u>Gp H</u>							
101	13	.69	.46	.38	.38	.08 ^a	.08 ^a
109	17	.76	.29	.18	.06	0	0
105	25	.72	.20	.24	.16	.12	.04
113	19	.58	.26	.26	.11 ^a	0	.21 ^a
108	32	.47	.66	.09	.09 ^a	.03 ^a	.03 ^a
110	25	.40	.48	.32	0	.12	0
\bar{X}	21.8	.60	.39	.25	.13	.06	.06
<u>Gp T</u>							
102	24	.63	.63	.21	.08	0	.04
112	17	.35	.53	.24	0	.06	0
103	32	.69	.22	.28	.06 ^a	.03 ^a	.03 ^a
107	52	.54	.46	.48	.08	.08	.08
106	30	.73	.53	.36	.07	.03	0
111	17	.53	.71	.29	.12	0	.12 ^a
\bar{X}	28.7	.58	.51	.31	.07	.03	.05

^aCategory seen only after the acquisition phase of training.

Receptor-Orienting Activity

S(F)	S(W)	S(C)	S(P)	R(W)	S(DW)	S(T)	Fa (r, l)	R (DW)	R(T)	R(C)
.69	.62	.38	.15	.23	.31	.15	.08	.15	0	.08
.71	.59	.47	.06	.18	.18	.12	.06	.12	0	.06 ^a
.64	.44	.20	.12	.28	.24	.08	.20	.24	.08	0
.68	.37	.26	.11	.11	.11	.05	.32	.16	0	0
.78	.38	.06	.16	.06	.03	.09	.28	0	0	0
.44	.52	0	.24	.20	.24	.04 ^a	.08	.16	.04 ^a	0
.66	.49	.23	.14	.18	.19	.09	.17	.14	.02	.02
.75	.71	.42	.21	.38	.08	.50	.29	.04	.08	0
.88	.41	.06	.29	.12	.18	.18	.12	.18	0	0
.63	.53	.13	.50	.31	.13	.13	.13	.13	.06	.03 ^a
.54	.35	.33	.54	.19	.12	.23	.21	.10	.06	.04
.53	.47	.27	.23	.13	.23	.37	.13	.17	.03	0
.76	.47	.59	.29	.29	.29	.24	.12	.24	.24	.12
.68	.49	.30	.34	.24	.17	.28	.17	.14	.08	.03

As Table 8 shows, despite wide individual differences, there was close agreement between the two groups not only in the rank-order of the categories, but also in the mean relative frequency of most of the categories of competing behavior. The main exceptions were S(P) and S(T), which occurred relatively more often for Gp T than Gp H. Thus the evidence even for a minimal quantitative difference in categories of competing behavior for the hungry and thirsty subjects was not great.

Table 9 lists the categories of gross movement and receptor-orienting accessory behavior, again in approximate rank-order for the two groups overall, and shows the proportion of CB and AB trials throughout training on which each category occurred for each subject and each group. For both groups, sniffing the floor and accessory hesitations were by far the most commonly seen accessory behaviors at every stage of training, with sniffing the center occurring somewhat less often. No other accessory behaviors occurred with notable frequency. There was no strong evidence for qualitative differences in the categories of accessory behavior shown by the two groups. Although Gp T showed two categories not seen for Gp H, viz., R(T) and R(W), both occurred only once, for one rat (107). Also, it is important to note that these behaviors were shown in competing form by the subjects of Gp H as well as Gp T (Table 8). Indeed, no categories of accessory behavior were observed which were not also seen in competing behavior form; this result supports the conclusion, suggested by the observed parallel changes in competing and accessory behavior

Table 9

Proportion of CB and AB Trials on Which Each AB Category Occurred in Experiment I

Subjects	Categories of Accessory Behavior											
	# Trials with AB	Gross Move- ment	AH	S(F)	S(C)	S(W)	Fa(r, l)	S(P)	S(T)	R(C)	R(T)	R(W)
<hr/>												
Gp H												
101	17	.65	.82	.29	.06	.06	.06	.06	0	.06	0	0
109	16	.44	.56	.56	0	.19	.19	0	.06	.06	0	0
105	19	.32	.84	.21	.11	.11	.11 ^a	0	0	0	0	0
113	23	.39	.74	.09	.04	.04	.04	.04	0	0	0	0
108	38	.53	.68	.18	.13	.13	.24	.08	0	0	0	0
110	26	.23 ^a	.69	0	.27 ^a	.23	.23	0	0	0	0	0
\bar{X}	23.2	.43	.72	.22	.10	.15	.15	.03	.01	.02	0	0
<hr/>												
Gp T												
102	24	.46	.79	.21	.17	.09	0	.08	.04	0	0	0
112	22	.45	.91	.18	.09	.09	.09	0	0	0	0	0
103	23	.48	.87	.13	.09 ^a	.04 ^a	.04 ^a	0	0	0	0	0
107	26	.58	.69	.38	.12	.05	0	0	.08	.04	.04	.04
106	22	.45	.68	.45	.05	.05	0	.05	.05	0	0	0
111	22	.50	.95	.23	.09	.09	0	0	0	0	0	0
\bar{X}	23.2	.49	.82	.26	.10	.02	.02	.02	.03	.01	.01	.01

^aCategory seen only after the acquisition phase of training.

throughout training, that competing and accessory forms of a given behavior differ from each other only quantitatively, that accessory behavior is in fact simply "weak" competing behavior. The rank-order and the relative frequency of the categories of accessory behavior were comparable for the two groups, except that Gp H showed facing-right or -left somewhat more often than Gp T.

Finally, two types of "sequencing" of competing and accessory behavior patterns across trials were observed on a small proportion of CB and AB trials. First, some individuals of both groups developed idiosyncratic behavior patterns that lasted from a few trials to several sessions. The first column of Table 10 shows for each subject and each group the proportion of CB and AB trials throughout training on which clear instances of such intra-individual sequencing occurred. These sequences differed from subject to subject, but almost always involved sniffing some part of the alleyway, e. g., sniffing the top and wall in A_2 (rat 106, trials 5, 7-12), or elongating out of SB, or hesitating or stopping, and sniffing the photocell in A_1 (rat 107, 39 trials throughout training). They often occurred in conjunction with other competing and accessory behavior not involving such sequencing. Less frequent were recurrent behavior sequences across subjects within a session (inter-individual), as is shown in the second column of Table 10. Early in training, when much competing and accessory behavior was occurring in similar categories and locus for all the subjects, it was difficult to discern such

Table 10

Proportion of CB and AB Trials Showing Intra- and Inter-
Individual Behavior Sequences in Experiment I

Subjects	Intra-Individual	Inter-Individual
<u>Gp H</u>		
101	0	0
109	0	.04
105	.18	.03
113	.21	.03
108	.29	0
110	.11	0
\bar{X}	.13	.02
<u>Gp T</u>		
102	0	.19
112	.54	.08
103	.11	.18
107	.70	.16
106	.46	.35
111	0	.07
\bar{X}	.30	.17

sequences since the "signal-to-noise" ratio was so small. After a few trials, when the overall level of competing and accessory behavior had decreased, and they occurred mainly in A_1 and involved few categories, the few instances of inter-individual sequencing were more easily identified. These sequences also primarily comprised bouts of sniffing, most often sniffing a circumscribed part of the floor, suggesting the tracing of other subjects by odor. This result is surprising since the floor of the alleyway was always thoroughly scrubbed with Lysol disinfectant and dried after every run, and subjects were never seen to engage in any behavior which would obviously correspond to leaving a pheromonal cue. Other competing and accessory behavior often occurred on trials showing inter-individual sequencing.

Neither shifts in reward magnitude nor the introduction of the insecticide stimulus were associated with an inordinate amount of sequencing of either type. The occasional periods of atypically long run times for several subjects, seen for example around trials 11-15 and 21-25 (Figs. 2 and 3), also did not involve disproportionate levels of intra- or inter-individual sequencing. There were wide individual differences within each group in the frequency of such sequences, especially intra-individual. Both kinds of sequencing were much more frequent overall for Gp T than Gp H.

Discussion

The present results demonstrate that the decrease in overall run time in the alleyway in the course of acquisition for individual rats reflects a large-scale, orderly decrease in the amount of competing and accessory behavior, but that the vigor of running also increases, within a much narrower range. Thus, the results of previous studies of competing behavior in alleyway acquisition (Cicala, 1961; Kello, unpublished experiment; King, 1959; Marx & Brownstein, 1963; Pereboom & Crawford, 1958; Smoot, 1964) are supported for single subjects, with rigorous measures of competing behavior and the running response, and these results are extended to include thirsty rats running to water. Hence, both the Hullian S-R view and the response-competition view of learning in the alleyway are shown to be inaccurate. However, both positions could easily be modified to account for the observed structure of acquisition in the alleyway. The S-R view would have to acknowledge the response-competition claim that all learning is selective learning, that even the "ideally simple" alleyway is necessarily a multiple-response, trial-and-error situation. Thus, following the S-R account of selective learning, with practice an instrumental response does increase slightly in vigor (provided that response vigor is correlated with reinforcement; cf., Logan, 1959, 1960), but more importantly, it competes more and more successfully with alternative responses, i.e., occurs more often (Hull, 1930; Kimble, 1961, p. 408; Siegel, 1945; Spence, 1956, 1958, 1960). The response-competition view would have to

acknowledge that in the absence of overt competing behavior the vigor of most instrumental responses can vary at least within a narrow range, and that such responses become effectively all-or-none responses only when practiced extensively (cf., Bolles, 1958b), as in free-operant situations. It is seen here that the vigor of noninstrumental behavior also varies, from full competing forms to weaker accessory forms.

The present results show that, as with acquisition, large changes in overall run time induced by other variables during rewarded training (differences in amount of reward in acquisition, shifts in amount of reward, introduction of an extra stimulus, and proximity to reward) also reflect changes in the amount of competing and accessory behavior, but that smaller changes in the rate of running per se also occur. This was illustrated in some detail for individual rats, both hungry and thirsty. It was found that amount of reward affects the rate of acquisition much more than the final level of performance at asymptote (Hammer, 1971; Pereboom & Crawford, 1958), though there were wide individual differences in the rate and orderliness of acquisition. The present results do not support Hammer's (1971) conclusion that, when competing behavior has dropped out, shifts in reward magnitude have little effect. The apparent magnitude of upshift effects was indeed small under these circumstances as Hammer showed, almost certainly reflecting a "ceiling effect" (Bower, 1961). But downshifts in amount of reward here at middle and late stages of training when runs were mainly stable DR's continued to have large decremental

effects on running for subjects who had not previously experienced the small reward magnitude. Hammer's data also show a downshift effect, though smaller than observed here.

The temporary disruptive effect of the insecticide extra stimulus observed here for most subjects of both groups seems comparable to "external inhibition" as reported by Pavlov (1927). Similar disruptions of an ongoing instrumental response have often been reported in the alley-way (Courtney, Reid, & Wasden, 1968; Gagné, 1941; Kello, 1972; McNamara & Wike, 1958; Winnick & Hunt, 1951) and in other situations as well (Bindra, 1961; Bruce, 1935; Hoffman & Overman, 1971; Smith, 1971; Wendt, 1936). The effects of the extra stimulus in the present experiment looked generally like the effects of a downshift in reward magnitude. In both cases the structure of behavior on the long trials immediately following these events closely resembled that on the long trials earlier in acquisition, a similarity suggested before in the maze-learning literature (Bruce, 1935). With prolonged exposure to the extra stimulus, as well as to reduced reward magnitude, run times decreased, and the underlying behavioral changes were similar to those seen earlier in acquisition.

The goal gradient in overall run time was not an "artifact" of competing behavior (Marx & Brownstein, 1963). The pattern was also shown by all of the hungry subjects and most of the thirsty subjects on the majority of their DR trials, on which no competing or accessory behavior

occurred. The slope of the gradient was, however, enhanced by the occurrence of competing and accessory behaviors, as King (1959) found, since such behaviors occurred most frequently in the first alleyway segment (cf., Marx & Brownstein, 1963).

The possibility that the observed variation in the rate of running in acquisition and with the other manipulations studied here might be due to the occurrence of overt competing behavior falling outside the usual definition cannot be strongly argued. First, subcriterial noninstrumental behaviors such as head swings occurred on less than 2% of all rated DR trials, and not preferentially on the slowest. Second, Premack (1965) has suggested, without elaboration, that rats may have several constant "intra-burst" rates of running corresponding to different gaits. If this were indeed the case, and if it could be argued that slower gaits can be considered competing behaviors, then a strict response-competition view of learning and performance in the alleyway could still be maintained. Setting aside the problems raised by extending the definition of competing behavior to include slower gaits, this position can be rejected on the basis of the present finding that run times on DR trials showing different gaits overlapped extensively.

The thirsty, water-rewarded rats showed much more variability in run time and more competing behavior throughout the experiment than the hungry, food-rewarded rats. Also, with the exception that rat 108 of Gp H showed much more accessory behavior than any thirsty subject (see

Table 9), Gp T generally showed more accessory behavior than Gp H. Overall, the behavior of the thirsty subjects appeared to be less affected by reinforcement than did the behavior of the hungry subjects. Thus, acquisition was slower for Gp T, and behavior was more variable in the presence of the extra stimulus (cf., Bruce, 1935) but usually less affected by upshifts or downshifts in amount of reward. It was also observed that the thirsty subjects showed a weaker goal gradient both overall and on DR trials alone, and that they galloped less and showed recurrent sequences of competing and accessory behavior more often than did the hungry subjects.

The finding that the performance of thirsty, water-rewarded rats is more variable than the performance of hungry, food-rewarded ones in the alleyway is directly counter to the implication of the results of T-maze and general activity studies comparing hungry and thirsty rats, and at least one alleyway study (Bolles, 1958a; Campbell & Cicala, 1961; Hall, 1955; Kintsch, 1962; Petrinovich & Bolles, 1954). It is also counter to the generalization in the older literature (e.g., Munn, 1950), based on Warden's (1931) studies with the Columbia obstruction apparatus, that 24-hr. thirst is "more motivating" than 24-hr. hunger. Rather, the present results closely parallel those reported by Bruce (1935) with hungry and thirsty rats in a multiple-unit maze. Bruce found that 24-hr. thirsty rats ran more slowly, made more errors, and showed more trial-to-trial variability in both performance measures than 24-hr. hungry rats.

The differences found here between hungry and thirsty rats might simply reflect quantitative differences in drive. Indeed, while the subjects of Gp H lost to 80-90% ad lib body weight in the course of the experiment, Gp T showed only a temporary loss followed by a gain back to approximately 100% ad lib weight, and in some cases more. Such changes are common for hungry and thirsty rats at this level of deprivation (Bolles & Petrinovich, 1956). To determine whether the observed differences between the hungry and thirsty rats reflect quantitative or qualitative differences in drive, it would be necessary to vary the deprivation level of subjects in one motivational condition to see if a point can be reached at which their performance corresponds to that of subjects in the other motivational condition at some fixed deprivation level (Shettleworth, 1972); this is a variant of Bitterman's (1960) "control by systematic variation." It is also possible that the observed differences in performance might reflect, to some extent, differences in amount of reward. It might be that at the drive levels used, say, five times as much water as was given would have resulted in performance for Gp T that was comparable to that for Gp H. In the absence of parametric studies of this type, the reasons for the difference in variability between the two groups cannot be determined.

However, at least one result suggests that quantitative differences in drive or reward magnitude may not be sufficient to account for the behavioral differences between the two groups. The thirsty subjects

showed a small average goal gradient, and showed this pattern on a relatively small proportion of their trials; some individuals of Gp T showed a negative goal gradient on the average (cf., Bruce, 1937). For hungry rats it is known that the average goal gradient is sharper with small amounts of reward (Crespi, 1942; Hull, 1934) and lower levels of deprivation (Hull, 1934). While decreasing the amount of reward or level of deprivation for hungry rats might result in as slow a rate of acquisition, as much competing and accessory behavior, and as much trial-to-trial variability as seen here for the thirsty rats, these operations should further enhance the goal gradient rather than weakening it. Thus the difference in the goal gradient for hungry and thirsty rats, as shown here, may in fact reflect a qualitative difference as a function of motivational condition, though further study is required to bear this out.

Reasons for the failure to find qualitative differences, or indeed any large quantitative differences, in the categories of behavior for the hungry and thirsty rats are not clear. It may be that over a wide range of conditions the same "appetitive behaviors" (Craig, 1918) for rats are associated with both hunger and thirst (see Hull, 1943), and that the alleyway does not provide stimulus conditions appropriate to separate hunger- and thirst-related behaviors. There has also been a failure to find qualitative differences in the "free behavior" of hungry and thirsty rats in simple open-field situations (Kello, unpublished observations; Prescott, 1970). Perhaps enriching either situation and providing opportunities for a wider

range of behavior (e.g., adding areas for digging, side alleys, or objects to manipulate) would reveal differences as a function of motivational state. Or, it might be that, in the unfamiliar alleyway situation, exploratory or curiosity behaviors predominate and interfere with the expression of hunger- or thirst-related behaviors. Although extraneous novel stimuli will engender competing and accessory behavior in the alleyway, strong arguments can be made against the common view that such behaviors are simply a response to unfamiliarity (e.g., Bindra, 1961; Estes, 1958; Hinde, 1970; Pereboom, 1957). For example, even when maximal these behaviors do not appear as a thorough exploration of the environment. Many parts of the apparatus are never "explored" by a given subject throughout training, while other parts, such as the floor in A_1 , are examined repeatedly. Also, competing and accessory behaviors occur as described even when subjects have been given an extensive period of pre-experimental exploration of the alleyway, rewarded or unrewarded (Bindra, 1963; Hammer, 1971; Kello, unpublished experiment; Pereboom & Crawford, 1958), and they may continue to occur for many hundreds of training trials (Cotton, 1953). Moreover, it is not clear in what sense the same environment should be more "novel" for subjects who are under weaker drive conditions or who are receiving smaller reward. It is also not clear why a novel decrease in reward magnitude should engender competing behavior while a novel increase does not.

It is not necessary to assume that competing and accessory behaviors

are exploratory behaviors elicited by novelty, or that they are random, unstructured, spontaneous activities. The view of the alleyway as a selective learning situation, supported here, suggests another account of these behaviors. Thus, running and the other behaviors may be seen as reflecting an organized response hierarchy, an initial range of non-random behavioral variation in the alleyway (though it is still not clear why hunger and thirst did not have differential effects on the range or relative frequency of behaviors in the hierarchy). During rewarded training the "other" behaviors which compete with the rewarded running response are selected out in an orderly way. Their occurrence becomes less frequent, and when they do occur they take up less time and occur in fewer bouts, involving fewer categories. Further, full competing behavior drops out faster than weaker accessory forms. Also, after a few trials these behaviors, especially full-competing forms, generally occur within a trial only where the selection for running is weakest, viz., in the early parts of the alleyway, farthest from reward.¹

¹Note that this observation suggests similarities between alleyway competing behavior and "interim activities" (Staddon & Simmelhag, 1971) and "adjunctive behaviors" (Falk, 1970) seen in some free-operant situations. These behaviors are all apparently irrelevant noninstrumental activities which occur primarily where reinforcement probability is lowest, viz., spatially or temporally farthest from reward. That these behaviors are not all identical, however, is suggested by the observation that alleyway competing behavior is most salient early and decreases with training, while interim and adjunctive behaviors develop and become more stereotyped with training.

It may be assumed that this selection process is situation-dependent. Thus a change in environmental conditions, not involving reward itself, engenders a temporary return in competing and accessory behavior of the same form as earlier in acquisition, with the same range and approximately the same rank-order of categories of competing and accessory behavior. An abrupt decrease in amount of reward involves directly weakening the selection for running. Therefore, downshifts have effects similar to the introduction of extra stimuli but, at least for hungry, food-rewarded subjects, even greater. In both cases, under the continuing selective effect of reinforcement, competing and accessory behaviors drop out as in acquisition. An abrupt increase in amount of reward increases the strength of selection for running, so that no competing or accessory behavior occurs. Up to this point, this account may be seen as an elaboration of a consistent S-R reinforcement view of selective learning, or as a variety of the response-competition view which attributes the dropping out of competing behavior specifically to the selective effect of reinforcement (cf., Staddon, 1972; Staddon & Simmelhag, 1971). The mechanism underlying the consistent changes in the vigor of running observed here, independent of any overt competing behavior, is not clear. These changes may reflect a direct effect of reinforcement on the strength of the selected response, or extinction "below zero" of (covert) competing behavior tendencies, or both. Observed quantitative variations in noninstrumental behaviors, from accessory to competing forms, pose a similar problem.

The occasional occurrence of repetitive sequences of competing and accessory behavior within- and between-subjects, and of periods of atypically long run times for several subjects, largely independent of such sequencing, have been observed before in the alleyway, but they have received little attention and are not well understood (Kello, unpublished experiment; Ludvigson & Sytsma, 1967; Pereboom & Crawford, 1958). In addition to the low overall frequency of such patterns, there is further evidence that the structure of behavior observed here was not dependent upon inter-subject interactions. Pilot experiments have shown that behavior in acquisition and in the presence of extra stimuli looks the same as shown here even when single subjects are run by themselves to the completion of training (Kello, unpublished experiment; see also Pereboom & Crawford, 1958).

EXPERIMENT II

A further implication of the view of the alleyway as a multiple-response, selective-learning situation was examined in this experiment. Since the removal of reward in extinction would eliminate selection for running, competing and accessory behavior of the same form as in the earliest stages of acquisition should return throughout the alleyway. And, since the rate of running varies little, at least in rewarded training, this return in competing and accessory behavior should largely account for the great increase in overall run time seen in extinction. Although there has been no detailed single-subject analysis of alleyway behavior in extinction, theoretical accounts of extinction in terms of "interfering response" tendencies are common, not only among response-competition theorists, but paradoxically, among some Hullian S-R theorists as well (Amsel, 1958; Estes, 1959; Guthrie, 1959; Kimble, 1961; Spence, 1960; Wendt, 1936). Since S-R theorists accord no role to interfering responses during continuously rewarded acquisition, they generally account for the occurrence of these behaviors in extinction by assuming that they are elicited by nonreward (e.g., "emotional" or "frustration" behaviors, Amsel, 1958; see Kimble, 1961; Spence, 1960). On the empirical side,

several studies have reported the general finding that competing behavior is in fact quite prominent in extinction and may thus account for part of the increase in overall run time, though it is not clear how much (e. g., Bindra, 1963; Marx & Brownstein, 1963; McCoy & Marx, 1965). Further, it is sometimes reported that specific categories of behavior seen earlier in acquisition are particularly likely in extinction, though it is not clear whether the range of behavior is extended in extinction (Hull, 1934; Kello, unpublished observations; Mackintosh, 1955; McNamara & Wike, 1958; Miller & Miles, 1936; Miller & Stevenson, 1936; Pryor, Haag, & O'Reilly, 1969; Ross, 1964). The present experiment attempted to provide the currently lacking descriptive analysis of the behavior of individual rats running to nonreward in extinction following continuously rewarded acquisition, and to thereby determine the form of competing behavior, and its contribution to the increase in overall run time, in extinction.

Also, a prediction not critical to the view of the alleyway as a selective learning situation was tested here, in two ways. It might be assumed that the more competing behavior which occurs on rewarded trials, the more that competing behavior tendencies are selected against, and thus the greater the relative strength of the tendency to run once running predominates (Staddon, 1972). The stronger the tendency to run, the more nonrewarded trials it should take in extinction before competing behavior returns. Thus, it may be predicted that any manipulation which encourages the temporary expression of competing behavior on rewarded trials

should increase resistance to extinction (see Amsel, 1972, for a similar prediction, and Bindra, 1961, for the opposite prediction). Consistent with this prediction, McNamara and Wike (1958) found that group-averaged resistance to extinction was increased by stimulus changes in acquisition unrelated to reward, though they did not present data showing to what extent these stimulus changes increased the amount of competing behavior in acquisition. It is also suggestive that subjects trained with small reward, and therefore presumably showing more competing behavior in acquisition, sometimes show greater resistance to extinction than subjects trained with large reward (Robbins, 1971). To test the prediction that the more competing behavior temporarily induced in acquisition, the greater the resistance to extinction, the present experiment compared the acquisition and extinction behavior of continuously rewarded rats with and without extra stimuli in acquisition.

One manipulation which reliably produces greater resistance to extinction is partial reinforcement (PRF) in acquisition. Does partial reinforcement yield more competing behavior in acquisition, before stable DR trials predominate, than does continuous reinforcement (CRF)? This is a fairly common prediction (e.g., Amsel, 1958, 1972; Estes, 1959; Weinstock, 1954). Several studies, inspired by the frustration theory (Amsel, 1958) or "habituation" (Weinstock, 1954) accounts of the partial reinforcement effect on extinction, in terms of interfering response tendencies during PRF acquisition, have compared the frequency of one or

two competing behaviors for CRF and PRF groups, but the results have been inconclusive (Robbins, 1971). Often both groups show the same amount overall (e.g., McCoy & Marx, 1965), but sometimes the PRF group shows slightly more competing behavior when its run time is longer (early acquisition) and less when its run time is shorter (late acquisition) than the CRF group (Goodrich, 1959; Jones & Bridges, 1966; McCoy & Marx, 1965). The possibility remains that the partial reinforcement effect may depend, not on specific experience with nonreward in acquisition, but only on the fact that such experience will strongly encourage the behavioral expression of competing behavior, thereby ultimately strengthening the tendency to run relative to the tendencies to engage in competing behaviors, and resulting in greater persistence of running when reward is completely removed. The present experiment tested this possibility by comparing the behavior of continuously and partially reinforced rats in acquisition and extinction, using strict measures of competing behavior and the instrumental response, as in Experiment I.

Method

Subjects and apparatus

The subjects were 10 male Long-Evans hooded rats approximately 120 days old at the first experimental session. The alleyway and recording equipment were the same as in Experiment I.

Pretraining

Upon arrival in the laboratory the subjects were caged singly in 24-hr. light and given food and water ad lib. They were handled at least 2-3 min. on each of the first 7 days and were handled and gentled intermittently across the remaining 36 days of pretraining. On pretraining day 20 all subjects were placed on a 1-hr. per day restricted feeding schedule, with water still available ad lib, on which they were maintained throughout the experiment. On days 35-43 the subjects were brought to the experimental room separately in three groups, at the approximate time they would be run during the experiment. Each group was exposed to the experimental room, set up for a session, and to typical equipment noises, for 45-60 min. on each of these days. Body weights were monitored daily from the beginning of pretraining through the end of the experiment. Under 23-hr. food deprivation the rats were quickly reduced to 80-90% ad lib weight, as in Experiment I.

Experimental procedure

Prior to the beginning of experimental training, the subjects were randomly assigned to either of three groups, Gp CRF (3 rats), Gp CRF-S (3 rats), and Gp PRF (4 rats). Gp CRF received continuous reinforcement throughout acquisition, i.e., every run terminated in reward in GB. Gp CRF-S also received continuous reinforcement throughout acquisition, and differed from Gp CRF only in that discrete environmental stimulus

changes, unrelated to reward, were presented on blocks of trials from trial 12-47, as shown in Table 11. No diffuse olfactory stimulus comparable to the insecticide spray in Experiment I was used because of possible lingering effects on the behavior of rats in the other groups. Gp PRF received two initial rewarded trials, then 50% partial reinforcement for the remainder of acquisition, with trials rewarded (R) or nonrewarded (N) in the following repeating sequence RRN RNN NRR NRN.

Subjects were run one trial on experimental days 1-3, two trials on day 4, and three trials per day from day 5 on. On days when more than one trial was run, the intertrial interval for a given subject was 12-15 min. The procedure in running an experimental session for a given group was as outlined in Experiment I. Gp CRF was run at 2:30 p.m., Gp PRF at 3:45 p.m., and Gp CRF-S at 5:15 p.m. The daily running order of the subjects within a group was randomized. After a session each subject was fed the difference, if any, between the amount he had received during that session and the amount given on three rewarded trials. Ten min. after this feeding in the animal colony, each subject was given 1-hr. access to food.

Each group ran 59 acquisition trials. On each rewarded trial subjects received 12 .045 g. Noyes pellets (.54 g.) in a food cup placed in GB out of view from the alley. On each nonrewarded trial (Gp PRF, and all groups in extinction) the empty food cup was present in GB. Subjects were kept in GB 30-40 sec. on N trials, which was close to the overall mean

Table 11

Extra Stimuli for Gp CRF-S

Stimulus #	Trials	Description
1	12-17	Complex GB stimulus; a black Plexiglas panel replaced the end door in GB, a similar black Plexiglas panel was clamped to the inside of the back wall of GB, the food pellets were placed on a black rectangle of sheet metal on the floor of GB instead of in the food cup, and a cross was made with masking tape on the outside of the clear Plexiglas top of GB. All these stimulus changes occurred in the short side-section of GB and were thus not visible from the alley.
2	18-23	Overall light level stimulus; the incandescent fixture was turned off, and overhead fluorescent lights were turned on (alleyway illuminance > 10 ft. candles).
3	24-29	Alleyway floor stimulus; the floor of the entire apparatus was not scrubbed with Lysol after every run and dried as usual, but was washed with clear cold water and left damp.
4	33-35	Pre-run auditory stimulus in SB; after the rat was placed in SB a 10 sec. tape recording of the squeals of a rat being held by his tail was played (80 db). The usual 70 db masking noise was off.
5	36-41	Complex SB stimulus; SB floor was covered with a ridged black rubber mat. When the rat was placed in SB a small (2 wt.) light bulb on the outside top of SB began blinking off every 0.75 sec. in synchrony with an audible "click."
6	42-47	A ₁ object stimulus; a metal tray, 30.5 cm long and 2.5 cm wide, was suspended from a wall in A ₁ (from mid-A ₁ to the beginning of A ₂) 6.4 cm up from the floor.

time to consume the pellets on R trials.

Following the 59 acquisition trials, each subject received 18 extinction trials. Other than the absence of reward on every trial in extinction, there was no change in the procedure from acquisition to extinction. At the end of the 6-day extinction period, the subjects of Gp PRF received further training. Rats 210 and 211, who had shown very little decrement in running across the 6 days of extinction, were given 24 more extinction trials across 8 days. Rats 204 and 208, who had shown highly erratic and unstable performance during acquisition, were shifted to CRF for 24 trials to check that their acquisition performance was in fact due to the PRF schedule, and not merely to individual idiosyncrasy.

Data analysis

Run times for each alleyway segment were automatically recorded, and each trial was video-taped. Analysis of the video-tapes was carried out as in Experiment I. No modification of the classification system presented in Experiment I was required. Trials 1-6 and 19-65 were analyzed independently by a second observer trained in the use of the classification system, but with only rudimentary knowledge of the experimental conditions and no knowledge of which subjects were in which conditions. Agreement as to whether a given behavior was competing or accessory was > 95%, agreement on the locus of occurrence was > 99%, and on specific categories was approximately 95%. All disagreements were resolved by

reviewing the video-tapes. Each run for each subject was observed on tape a minimum of seven times by the experimenter, including at least two times after every other run was analyzed.

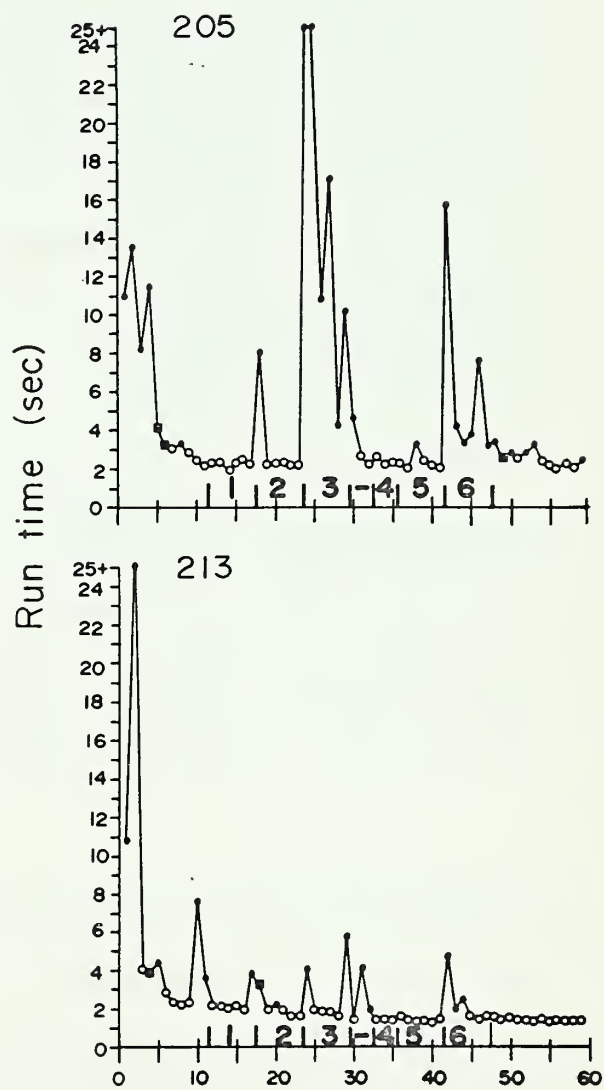
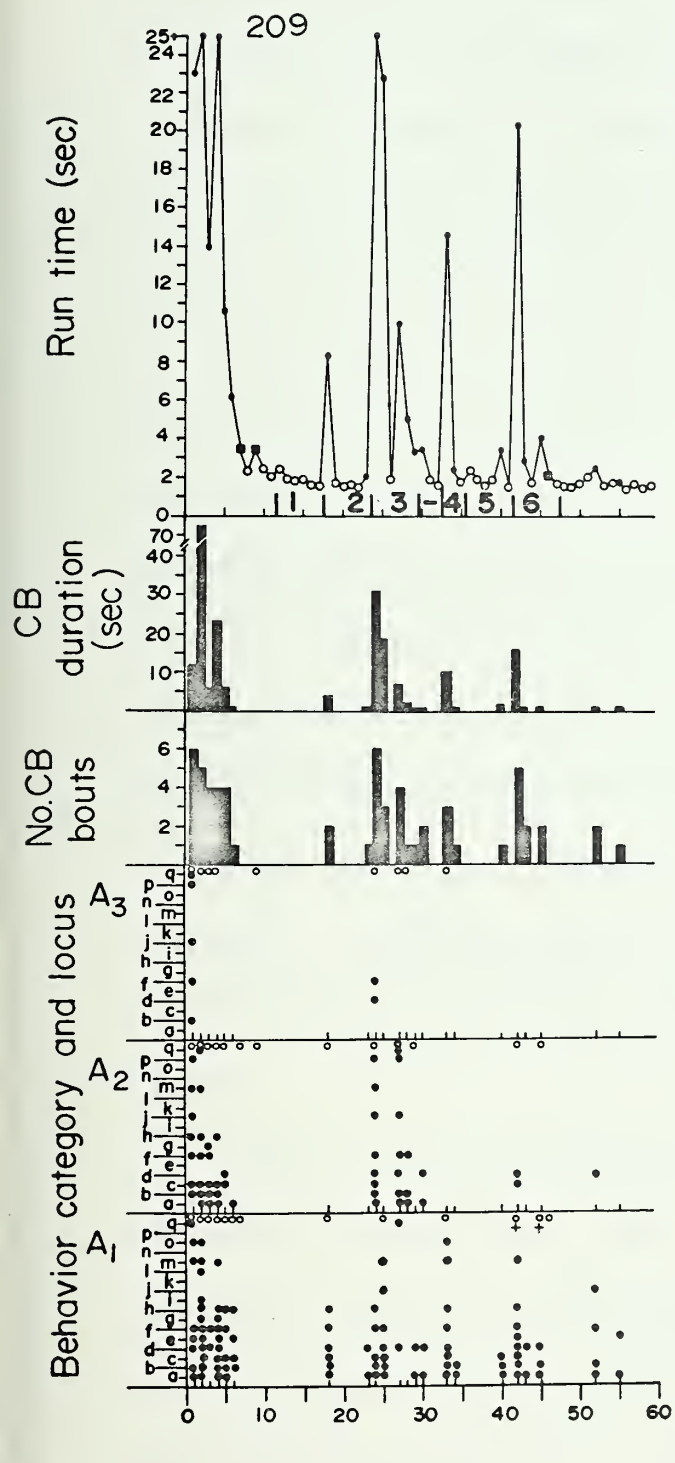
Results

Acquisition

For the CRF subjects, run time decreased somewhat more smoothly and rapidly, with less trial-to-trial variability than for most of the hungry subjects in Experiment I. With the relatively large amount of reward received here (12 pellets), all reached a stable DR asymptote by trial 20-25, showing only occasional CB or AB trials thereafter. Otherwise, acquisition looked like that seen for the hungry subjects in Experiment I. Because of this, and because typical CRF acquisition for this experiment can be seen in detail in Fig. 9 for rat 209 up to trial 17, trial-by-trial acquisition data for Gp CRF are not shown.

Figure 9 shows run time for each trial of acquisition, coded as CB, AB, or DR, for each subject of Gp CRF-S. In addition, the time spent in competing behavior per CB trial, the number of bouts of competing behavior per CB trial, the locus and categories of competing behavior, and the locus of accessory behavior are shown for each trial, as in Experiment I, but here only for one representative subject, rat 209. The numbers 1-6 in the top panel denote the extra stimuli. It is seen that some of the extra stimuli presented to the subjects of Gp CRF-S disrupted running. Stimuli

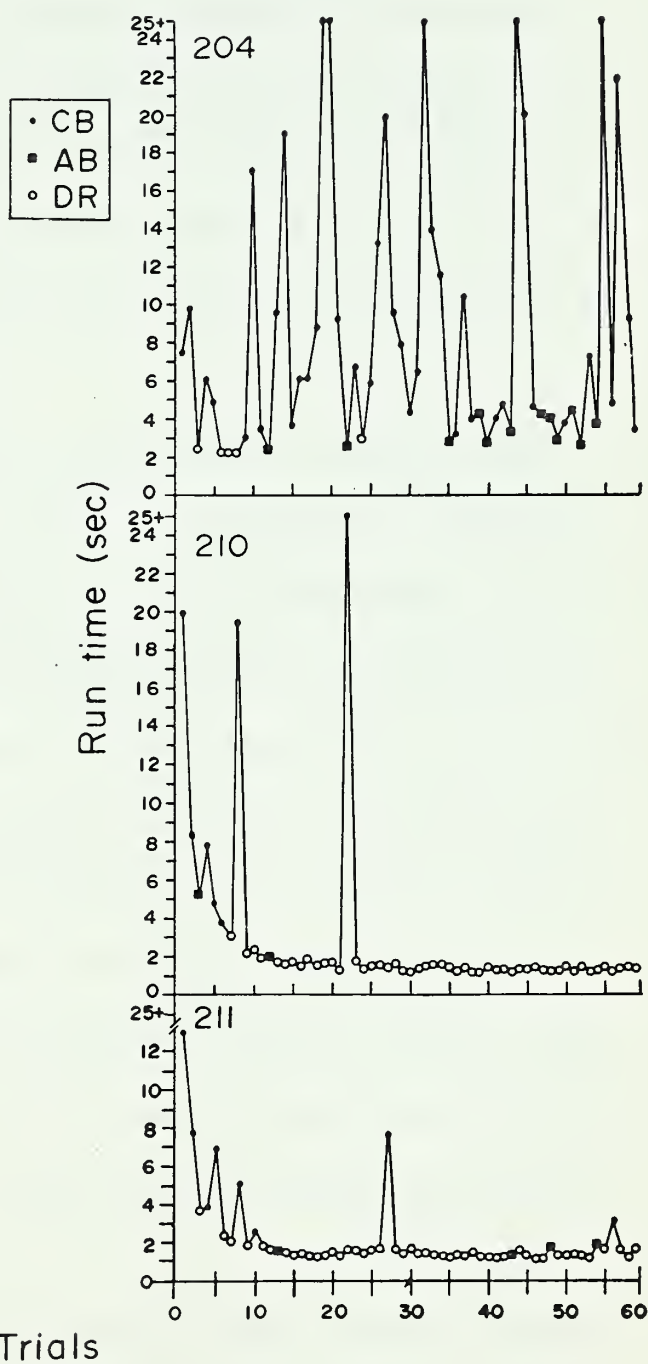
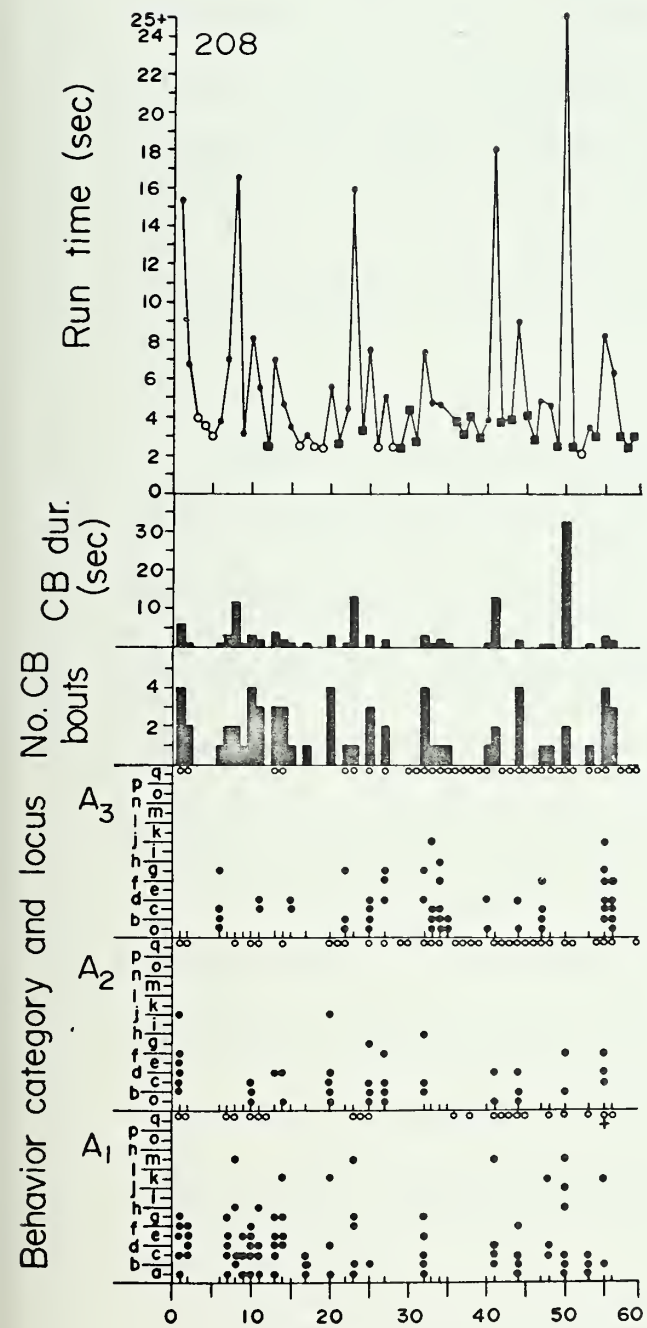
Fig. 9. Behavior in Acquisition for Gp CRF-S.



#3 and #6 (damp floor and A₁ tray) had the largest and most consistent disruptive effects, comparable to those seen for some subjects in Experiment I with the insecticide stimulus, and in some cases of greater magnitude. Long CB trials returned for all subjects, but especially rats 209 and 205, after the introduction of these two stimuli. As is shown for rat 209, these long trials involved long-duration competing behavior in multiple bouts with many categories, occurring widespread in the alleyway along with accessory behavior. The magnitude of the disruptive effect in the presence of a given extra stimulus decreased across trials, and as run time decreased the underlying behavioral changes for all subjects paralleled those in early acquisition, as shown for rat 209. Stimulus changes involving the goal box (#1) had no effect, and changes in the start box (#4 and #5) had only slight effects for rats 209 and 205, and no effect for rat 213. Throughout acquisition rat 213 showed consistently less disruption of running by the extra stimuli than did the other subjects of Gp CRF-S.

Figure 10 shows overall run time on each trial of acquisition for the PRF subjects, and a fuller trial-by-trial description of behavior for rat 208. In Gp PRF, rats 204 and 208 showed very few DR trials after nonrewarded trials were begun (trial 5). Their times on subsequent CB and AB runs were extremely variable, with long-duration, multiple-bout, multiple-category competing and accessory behavior occurring throughout the alleyway, as on the first few acquisition trials. They did not reach a stable

Fig. 10. Behavior in Acquisition for Gp PRF.



asymptote even by 59 trials. Rats 210 and 211, however, showed a very different kind of adjustment to the PRF schedule. After some typical early acquisition trials involving widespread competing and accessory behavior, and one or two CB trials just after nonreward was introduced, a minimal disruption, rats 210 and 211 showed mostly fast, stable DR runs, with run times slightly but consistently faster throughout (e.g., \bar{X} for last acquisition session = 1.40 sec.) than those for Gp CRF (\bar{X} = 1.62 sec.).

Table 12 summarizes for each subject and each group the total amount of competing and accessory behavior in acquisition. Within Gp PRF means are also presented separately for rats 204 and 208, and for rats 210 and 211. Overall, Gp CRF clearly showed the least competing and accessory behavior in acquisition, Gp CRF-S much more, and Gp PRF the most. However, the group average for Gp PRF is quite misleading, as rats 210 and 211 together showed fewer trials with accessory behavior and fewer CB trials even than Gp CRF, and only slightly more total time in competing behavior, due to one long CB trial (#22) for rat 210. There was some overlap among the individuals of all the groups on each measure presented here, underscoring the range of individual differences seen in this experiment.

Compared to the continuously rewarded, hungry subjects in Experiment I, the PRF subjects all showed an unusually high frequency of competing, and especially accessory behavior, in A_3 (see rat 208, Fig. 10).

Table 12
Amount of Competing and Accessory Behavior
During Acquisition

Subjects	# Trials with AB	# CB Trials	Time in CB (Sec.)
<u>Gp CRF</u>			
201	10	14	54.90
203	16	12	83.56
206	12	5	10.95
\bar{X}	12.7	10.3	49.80
<u>Gp CRF-S</u>			
205	20	25	199.99
209	18	22	215.75
213	7	14	62.23
\bar{X}	15	20.3	159.32
<u>Gp PRF</u>			
204	48	42	497.99
208	46	30	119.63
\bar{X}	47	36	308.81
210	8	7	86.82
211	10	8	19.32
\bar{X}	9	7.5	53.07
\bar{X}	28	21.7	180.94

This A_3 behavior almost always included slowing or stopping and sniffing the floor or walls. The high level of A_3 competing and accessory behavior for Gp PRF can be seen in Table 13, which summarizes for each subject and each group the proportion of trials throughout acquisition, given competing or accessory behavior, on which competing and accessory behavior occurred in each alleyway segment. Note that the A_1 bias of competing behavior was very weak for Gp PRF, and that accessory behavior was in fact strongly biased to A_3 . In Gp CRF, rats 203 and 206 showed the strong A_1 bias in competing behavior characteristic of the hungry subjects of Experiment I. However, rat 201 did not, and both rat 201 and rat 203 showed much competing behavior, especially hesitating or stopping and sniffing the floor or walls, in latter parts of A_2 and A_3 . Further, the CRF subjects as a group showed accessory behavior in A_3 about as frequently as they did in A_1 . These results were not seen for the continuously rewarded rats in Experiment I. The subjects of Gp CRF-S all showed a consistently higher frequency of competing and accessory behavior in A_1 than in A_3 , as in Experiment I, although rat 205 also showed a rather high frequency of competing and accessory behavior, usually involving floor-sniffing, in A_3 . These results overall suggest some influence of the PRF subjects on the behavior of some of the concurrently run, continuously rewarded subjects.

The similar patterns of competing and accessory behavior in latter parts of the alleyway, characteristic of the PRF subjects and some of the

Table 13

Proportion of Total CB and AB Trials in Acquisition on Which
Competing and Accessory Behavior Occured in Each
Alleyway Segment in Experiment II

Subjects	A_1		A_2		A_3	
	CB	(AB)	CB	(AB)	CB	(AB)
<u>Gp CRF</u>						
201	.43	(.30)	.50	(.50)	.36	(.50)
203	.92	(.88)	.58	(.63)	.42	(.50)
206	1.00	(.50)	0	(.08)	.20	(.67)
\bar{X}	.78	(.56)	.36	(.46)	.33	(.56)
<u>Gp CRF-S</u>						
205	.72	(.70)	.36	(.50)	.44	(.30)
209	.95	(.72)	.55	(.72)	.09	(.50)
213	.93	(.71)	.29	(.43)	.21	(.14)
\bar{X}	.87	(.71)	.40	(.55)	.25	(.31)
<u>Gp PRF</u>						
204	.79	(.65)	.26	(.31)	.38	(.85)
208	.67	(.48)	.40	(.74)	.50	(.76)
210	.71	(.63)	.14	(.38)	.43	(1.00)
211	.50	(.30)	.63	(.40)	.50	(1.00)
\bar{X}	.67	(.52)	.36	(.46)	.45	(.90)

continuously rewarded subjects, were not a simple result of behavior "sequencing," as described in Experiment I. Table 14 shows for each subject and each group the proportion of CB and AB trials clearly involving intra- and inter-individual behavior sequencing. Also shown is the proportion of sequencing trials involving A_3 sequencing. It is seen that there was little inter-subject sequencing at all in this experiment, as in Experiment I, and that few of the inter-individual sequencing trials involved A_3 patterns. High levels of intra-individual sequencing were seen only for rat 201 of Gp CRF, and the highly variable rats 204 and 208 of Gp PRF. Of these subjects only rat 201 showed high levels of intra-individual sequencing in A_3 . As these data suggest, most competing and accessory behavior in A_3 as well as in other parts of the alleyway did not appear in recurrent patterns either within- or between-subjects, but occurred intermittently, in "isolation."

Even when no competing or accessory behavior occurred for the PRF subjects, their run times were relatively slow in A_3 . Table 15 shows for each subject and each group the mean run time in each alleyway segment averaged across all DR trials in acquisition. It is seen that in Gp PRF rats 210 and 211 failed to show average A_1 times longer than A_2 times, and showed by far the longest run times in A_3 . Rat 208 showed only a very slight positive goal gradient on the average, and also showed the longest DR times in A_3 . Only rat 204 showed a large and consistent DR goal gradient. However, almost all of this subject's DR trials

Table 14

Proportion of CB and AB Trials Showing Intra- and Inter-
Individual Behavior Sequences, and Proportion of
Sequences Occurring in A_3 , During Acquisition
in Experiment II

Subjects	Intra-Individual		Inter-Individual	
	Overall	(A_3)	Overall	(A_3)
<u>Gp CRF</u>				
201	.59	(.70)	.06	(1.0)
203	0	-	.05	0
206	0	-	0	-
\bar{X}	.20	(.70)	.04	(.50)
<u>Gp CRF-S</u>				
205	.14	0	.04	0
209	.08	0	.08	0
213	.13	0	.06	0
\bar{X}	.12	0	.06	0
<u>Gp PRF</u>				
204	.70	(.24)	.04	(.50)
208	.60	(.20)	.06	(.33)
210	0	-	0	-
211	0	-	.08	0
\bar{X}	.33	(.22)	.05	(.28)

Table 15

Mean DR Time (Sec.) per Alleyway Segment During
Acquisition in Experiment II

Subjects	A ₁	A ₂	A ₃	Proportion A ₁ > A ₂
<u>Gp CRF</u>				
201	.61	.58	.69	(.65)
203	.65	.58	.66	(.88)
206	.61	.56	.66	(.83)
\bar{X}	.62	.58	.67	(.79)
<u>Gp CRF-S</u>				
205	.71	.71	.81	(.47)
209	.63	.55	.56	(.89)
213	.60	.52	.57	(.84)
\bar{X}	.65	.59	.65	(.73)
<u>Gp PRF</u>				
204	.93	.74	.78	(.80)
208	.91	.89	.96	(.56)
210	.43	.44	.60	(.48)
211	.43	.43	.60	(.56)
\bar{X}	.68	.63	.73	(.60)

occurred early in training, and not under partial reinforcement. Again, some of the continuously rewarded subjects showed results comparable to those of the PRF rats, viz., marked slowing in A_3 on DR trials. While all the rats in Gp CRF showed a decrease in DR run time from A_1 to A_2 on the majority of their DR trials, all showed the longest times on the average in A_3 . In Gp CRF-S, rats 209 and 213 showed a positive goal gradient on a high proportion of their DR trials. But rat 205 did not show an average positive goal gradient, and showed by far the longest times of all in A_3 . Again, these results were not seen for the hungry, continuously rewarded subjects in Experiment I.

The relative frequency of each category of competing behavior in acquisition for each subject and each group is summarized in Table 16. The categories of gross movement and receptor-orienting competing behavior are listed in order of their overall frequency in Experiment I (as in Table 8). Categories occurring only after extra stimuli were introduced at trial 12 for Gp CRF-S, or only after nonreward was introduced at trial 5 for Gp PRF, are separately marked. Rearing and sniffing at the tray in A_1 (stimulus #6) for Gp CRF-S are not shown. The range of categories seen was the same as in Experiment I for each of the groups, except that Gp PRF failed to show rearing in the center during acquisition. Also as in Experiment I, the most frequently occurring categories of competing behavior were stopping and hesitating and sniffing the floor and walls, and the rank-order of all the categories for each group varied little

Table 16

Proportion of CB Trials on Which Each CB Category
Occurred During Acquisition in Experiment II

Subjects	Categories of Competing Behavior					
	Gross Movement					
	ST	H	E	T 1/2 ret	T 1/4	F
<u>Gp CRF</u>						
201	.57	.57	.14	0	.14	0
203	.75	.67	.25	.08	.08	.08
206	.60	.20	.20	.40	.20	0
\bar{X}	.64	.48	.20	.16	.14	.03
<u>Gp CRF-S</u>						
205	.80	.44	.12 ^a	.16 ^a	.04 ^a	.40
209	.74	.73	.26	.30	.04	.13
213	.79	.36	.07	0	.07	0
\bar{X}	.78	.51	.15	.15	.05	.18
<u>Gp PRF</u>						
204	.67	.50	.40	.24 ^a	.19 ^a	.29 ^a
208	.70	.60	.27	.13 ^a	0	0
210	.75	.38	.13 ^a	.38 ^a	.13 ^a	0
211	.75	.38	.13	.13	0	0
\bar{X}	.72	.47	.23	.22	.08 ^a	.07 ^a

^aCategory seen only after introduction of extra stimuli (CRF-S) or nonreward (PRF).

Receptor-Orienting Activity

S(F)	S(W)	S(C)	S(P)	R(W)	S(DW)	S(T)	Fa (r, l)	R (DW)	R(T)	R(C)
1.00	.50	.36	.14	.14	0	.14	0	0	0	0
.83	.75	.75	.25	.33	.08	.17	.08	.08	.08	.08
1.00	.40	.20	0	0	0	0	0	0	0	0
.94	.55	.44	.13	.16	.03	.10	.03	.03	.03	.03
.80	.40	.28	.08	.24	.08 ^a	.16	.04 ^a	.04 ^a	.12	0
1.00	.52	.57	.13	.39	.04	.22	0	.04	.13	.13
.79	.50	.29	.36	.07	.14	.14	.07 ^a	.07	.07	0
.86	.47	.38	.19	.23	.09	.17	.04 ^a	.05	.11	.04
.83	.71	.31	.10 ^a	.21 ^a	.31	.07 ^a	.05 ^a	.26	.02 ^a	0
.83	.83	.37	.37	.16 ^a	.03 ^a	.20	.13 ^a	.03	0	0
.50	.75	.50	.13 ^a	.25	.38	0	0	.25	0	0
.75	.88	.63	0	.13 ^a	0	.13	0	0	0	0
.73	.79	.45	.15	.19	.18	.10	.05 ^a	.14	.01 ^a	0

from that seen in Experiment I. The relative frequency of the more common categories varied little on the average from group to group, with the exception that the subjects of Gp PRF showed a consistently higher relative frequency of wall-sniffing and somewhat less floor-sniffing than the subjects of the other groups. It can be seen that there were no categories associated exclusively with extra stimuli or with nonreward, although some minor categories occurred for Gps CRF-S and PRF only after these changes (Fa (r, 1) for both groups, and T 1/4, F, and R(T) for Gp PRF). Each category shown by an individual subject only after a change in conditions was usually shown by others in the same group before the change, and was in any case shown by subjects of Gp CRF, not experiencing either extra stimuli or nonreward in acquisition. As Table 17 shows, the range, rank-order, and frequency of categories of accessory behavior were also very similar for the three groups. Floor-sniffing and accessory hesitations were by far the most frequent, with sniffing in the center occurring somewhat less often. Also, Gp PRF showed somewhat more accessory wall-sniffing than the other two groups, and Gp CRF less sniffing in the center. It is seen that little accessory photocell-sniffing occurred, none for Gp CRF, and none for the other two groups before changes in reward or environmental conditions. Too much emphasis should not be placed on this observation, however, since photocell-sniffing in competing form occurred in early acquisition for subjects of all groups. It is of interest that, while every category of accessory behavior seen here was also seen

Table 17

Proportion of CB and AB Trials on Which Each AB Category
Occurred During Acquisition in Experiment II

Subjects	Categories of Accessory Behavior					
	Gross Movement	Receptor-Orienting Activity				
	AH	S(F)	S(C)	S(W)	Fa(r, l)	S(P)
<u>Gp CRF</u>						
201	.50	.90	.10	0	0	0
203	.50	.88	.19	0	.13	0
206	.42	.92	.08	.08	.17	0
\bar{X}	.47	.90	.12	.03	.10	0
<u>Gp CRF-S</u>						
205	.35	.80	.20	.05 ^a	0	.05 ^a
209	.72	.83	.22	.22	.06 ^a	0
213	.14 ^a	.71	.29	0	0	0
\bar{X}	.40	.78	.24	.09	.02 ^a	.02 ^a
<u>Gp PRF</u>						
204	.35 ^a	.98	.08	.10	0	0
208	.47 ^a	.85	.17	.32 ^a	.23 ^a	.11 ^a
210	.38	.88	.38	.25	0	0
211	.70	.60	.20	.20	.30	0
\bar{X}	.48	.83	.21	.22	.13	.03 ^a

^aCategory seen only after introduction of extra stimuli (CRF-S) or nonreward (PRF).

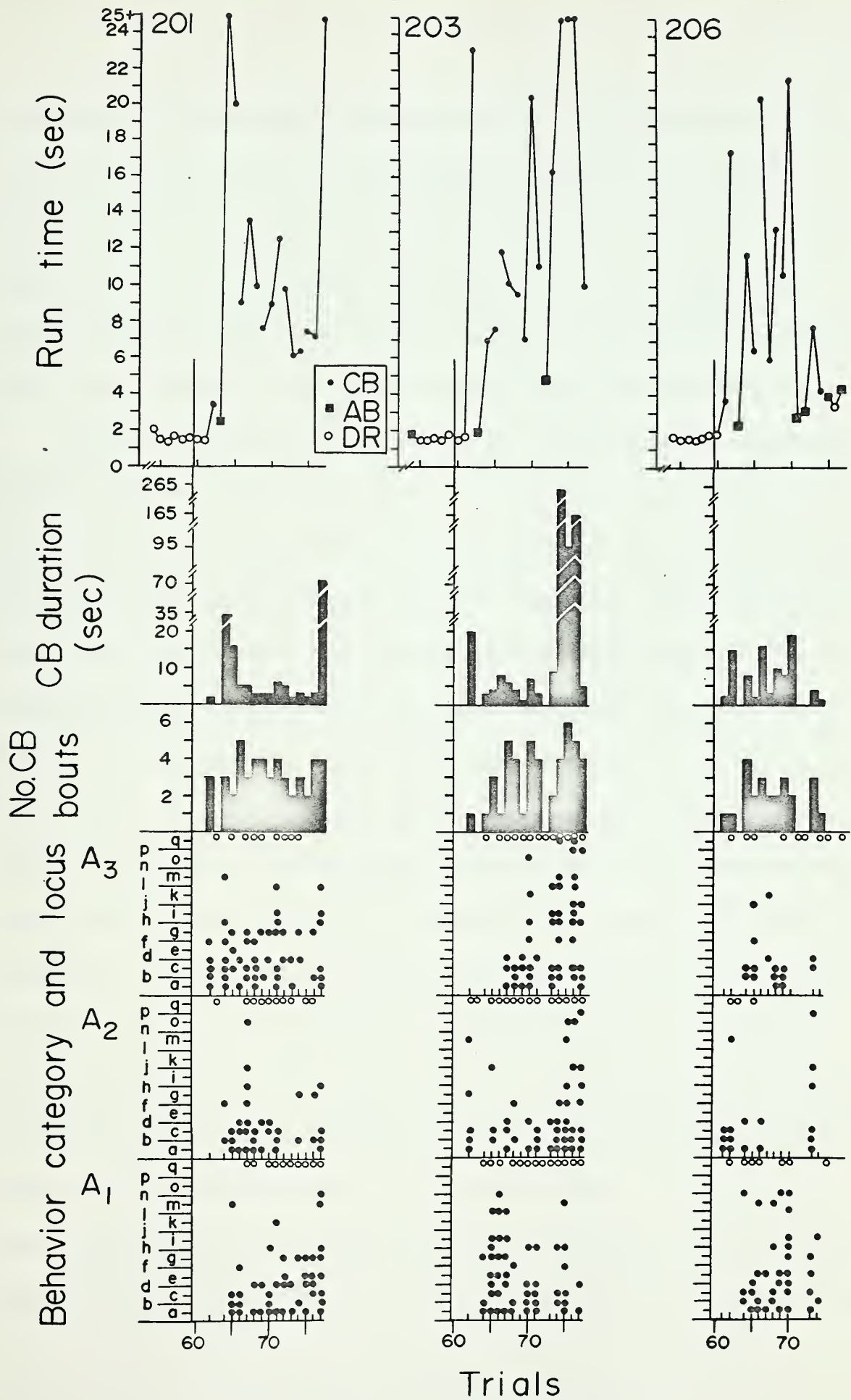
in Experiment I, in approximately the same rank-order, the range was narrower here; four of the least frequent accessory behaviors in Experiment I were not seen at all in acquisition here (R(W), R(C), S(T), and R(T)).

Finally, a period of slightly longer run times for several subjects was seen in acquisition, at trials 50-56 (rats 201 and 203, not shown; rats 209 and 205, Fig. 9; rats 208, 204, and 211, Fig. 10). As in Experiment I, this increase in run time, corresponding to the occurrence of competing and accessory behavior, was not a function of overt behavior sequencing.

Extinction

Figure 11 presents a description, plotted as in previous figures, of the behavior of each individual in Gp CRF during extinction. Run times for the last two acquisition sessions are also shown. Points representing run times on the last trial of a given session and the first trial of the next session are not connected, to facilitate assessment of the "spontaneous recovery" (Pavlov, 1927) of run time from one session to the next. It is seen first that long run times returned after a very few nonrewarded trials (2-4). These long trials invariably involved competing behavior, and usually accessory behavior as well. The competing and accessory behavior returned first in the latter parts of the alleyway for all the CRF subjects, in A_3 for rat 201 and in A_2 for rats 203 and 206, before

Fig. 11. Behavior in Extinction for Gp CRF.



spreading quickly throughout the alleyway. The long CB trials characteristic of extinction closely resembled typical long runs in the earliest stages of acquisition. As can be seen for each subject in Fig. 11, these long trials showed long-duration competing behavior in multiple bouts throughout the alleyway, with multiple categories occurring on each trial. Also, much accessory behavior occurred throughout the alleyway.

Table 18 shows the relative frequency of the categories of competing behavior and averaged for each group for the 18 trials of extinction. The order in which the categories are listed is the same as in Table 16. Categories seen only in extinction are separately marked. The range of categories was the same as in acquisition for both continuously rewarded groups; Gp PRF failed to show three minor categories (Fa (r, l), R(T), and R(C)). Also, the rank-order for groups overall was quite similar to that in acquisition, and in Experiment I, with only minor exceptions, e.g., R(DW) for Gp CRF. In Gp CRF some subjects (rats 201 and 206) showed categories of competing behavior in extinction which they had not shown in acquisition. However, they were not "new" behaviors, peculiar to extinction (e.g., emotional or frustration-elicited behaviors). They were all seen in acquisition for other CRF subjects. Accessory behavior in extinction (Table 19) also did not differ markedly from that in acquisition for the CRF subjects, though there were some minor changes. Thus the frequency of accessory wall-sniffing increased in extinction. Also, the range was extended, in that rat 203 showed accessory photocell- and top-sniffing,

Table 18

Proportion of CB Trials on Which Each CB Category Occurred
During Extinction in Experiment II

Subjects		Categories of Competing Behavior					
	# CB Trials	Gross Movement					
		ST	H	E	T 1/2 ret	T 1/4	F
<u>Gp CRF</u>							
201	15	.80	.87	.33	.20 ^a	.07	.07 ^a
203	14	.79	.64	.21	.29	.07	.21
206	11	.82	.64	.45	.36	.18	0
\bar{X}	13.3	.80	.72	.33	.28	.11	.09
<u>Gp CRF-S</u>							
205	13	.62	.46	.31	.38	.08	.38
209	12	.75	.92	.17	.08	.08	.08
213	13	.77	.69	.46	.31	.23	.08 ^a
\bar{X}	12.7	.71	.69	.31	.26	.13	.18
<u>Gp PRF^b</u>							
204	12	.58	.17	.58	.08	.25	.58
208	13	.54	.54	0	0	0	0
\bar{X}	12.5	.56	.36	.29	.04	.13	.29

^aCategory seen only in extinction.

^bRats 210 and 211 showed no CB trials during the 18-trial extinction period.

Receptor-Orienting Activity

S(F)	S(W)	S(C)	S(P)	R(W)	S(DW)	S(T)	Fa (r, 1)	R (DW)	R(T)	R(C)
.87	.67	.33	.67	.33	.13 ^a	.07	.07 ^a	.13 ^a	0	0
1.00	.93	.43	.36	.58	.43	.21	.07	.43	.14	.14
1.00	.73	.18	.18 ^a	.18 ^a	.27 ^a	.18 ^a	.09 ^a	.18 ^a	.09 ^a	0
.96	.78	.31	.40	.36	.28	.15	.08	.25	.08	.05
.77	.31	0	0	.23	0	0	.08	0	0	0
.92	.50	.67	.17	.25	.08	.42	0	.08	.17	.25
.77	.77	.38	.69	.31	.15	.08	.31	.15	.08	.08 ^a
.82	.53	.35	.29	.26	.08	.17	.13	.08	.08	.11
.58	.58	.17	0	.08	.17	0	0	.17	0	0
.92	.62	.54	.08	0	.08	.15	0	0	0	0
.75	.60	.36	.04	.04	.13	.08	0	.09	0	0

Table 19

Proportion of CB and AB Trials on Which Each AB Category Occurred
During Extinction in Experiment II

Subjects	Categories of Accessory Behavior								
	# Trials with AB	Gross Movement	Receptor-Orienting Activity						
		AH	S(F)	S(C)	S(W)	Fa(r, l)	S(P)	S(T)	R(C)
<u>Gp CRF</u>									
201	13	.46	1.00	0	.08 ^a	.15 ^a	0	0	0
203	16	.56	.94	.25	.44 ^a	.19	.06 ^a	.06 ^a	0
206	12	.50	.92	0	.08	.08	0	0	0
\bar{X}	13.7	.51	.95	.08	.20	.14	.02 ^a	.02 ^a	0
<u>Gp CRF-S</u>									
205	13	.38	1.00	0	0	0	0	0	0
209	14	.71	.86	.21	.29	0	.07 ^a	0	.07 ^a
213	12	.42	.83	.25	.33 ^a	.08 ^a	0	0	0
\bar{X}	13	.50	.90	.15	.21	.03	.02	0	.02 ^a
<u>Gp PRF^b</u>									
204	13	.54	1.00	0	0	0	0	0	0
208	17	.35	.82	.29	.24	.18	.06	0	0
\bar{X}	15	.45	.91	.15	.12	.09	.03	0	0

^aCategory seen only in extinction.

^bRats 210 and 211 showed no accessory behavior during the 18-trial extinction period.

not seen for any CRF subjects in acquisition. However, these categories, and other categories seen for the first time in extinction, were all shown in competing form in acquisition.

Figure 12 shows extinction data for the individuals of Gp CRF-S, plotted as for Gp CRF, and Table 20 summarizes the mean run time for both groups of continuously rewarded subjects in extinction, in blocks of 3 trials. The onset of long trials in extinction was slightly slower for Gp CRF-S than for Gp CRF. Mean run time across the first 3 extinction trials for Gp CRF-S was 2.79 sec., and for Gp CRF was 6.22 sec. Also, run times greater than 5 sec. returned after a mean of 4.67 trials for Gp CRF-S, compared to 2.67 for Gp CRF. There was overlap among the individuals of the two groups. Thus, as can be seen in Figs. 11 and 12, while rat 205 clearly showed greater initial resistance to extinction than any CRF subject, rat 201 (CRF) was comparable to rat 213 (CRF-S), and showed greater resistance to extinction at least across the first 4 trials than rat 209 (CRF-S). Run times for the two groups overall were comparable from the second to the fourth block of extinction trials, but on the last two blocks of trials Gp CRF again showed longer run times than Gp CRF-S (Table 20), due largely to the very long times for rat 203 (see Fig. 11).

As with Gp CRF, once running began to break down and long run times returned, trials for the CRF-S subjects looked like those in early acquisition, with long-duration, multiple-bout, multiple-category

Fig. 12. Behavior in Extinction for Gp CRF-S.

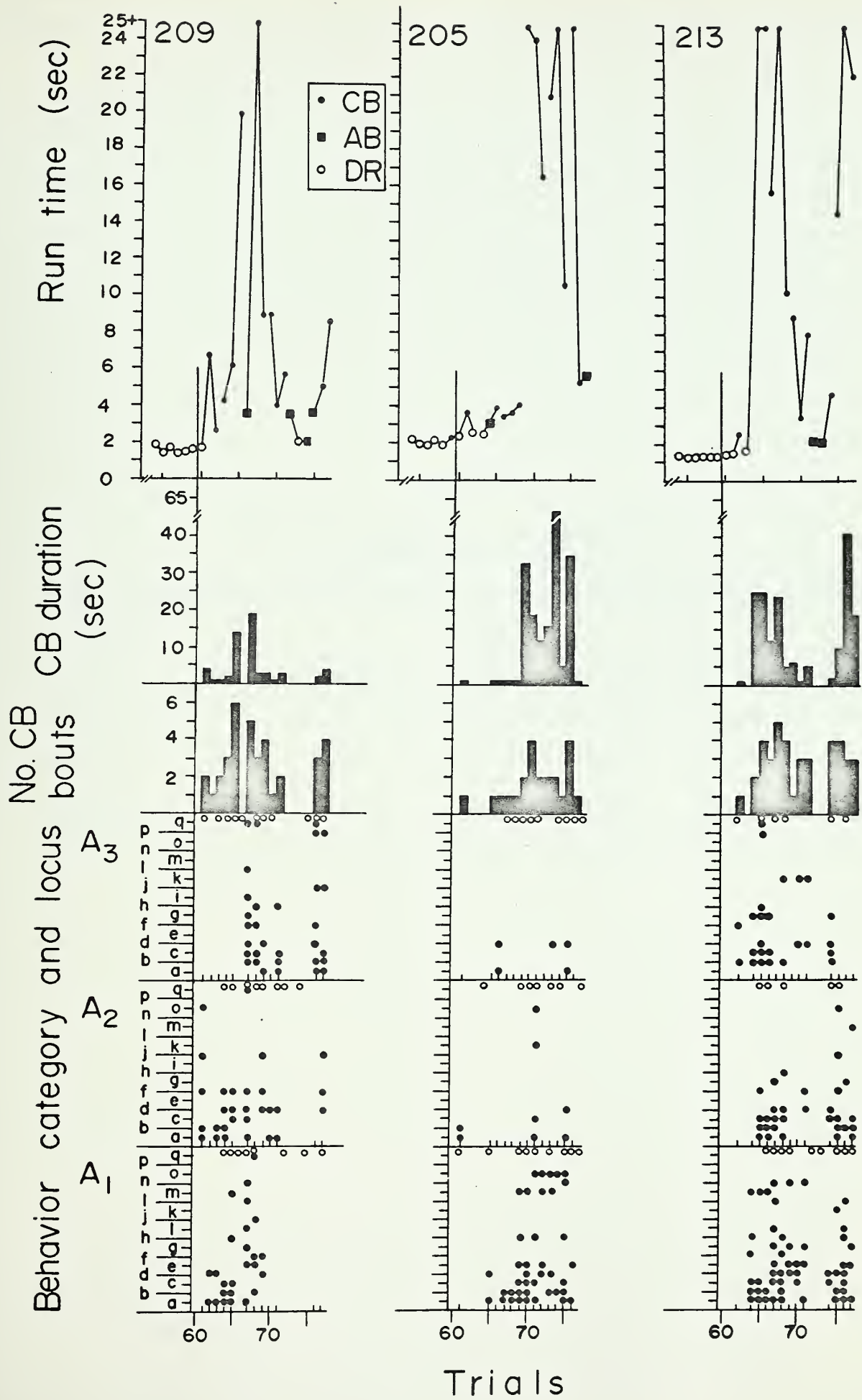


Table 20

Mean Run Time (Sec.) in Extinction for
Gp CRF and Gp CRF-S

Subjects	Trials					
	60-62	63-65	66-68	69-71	72-74	75-77
Gp CRF	6.22	10.91	11.52	11.47	36.63	43.06
Gp CRF-S	2.79	10.89	11.45	13.03	12.87	16.65

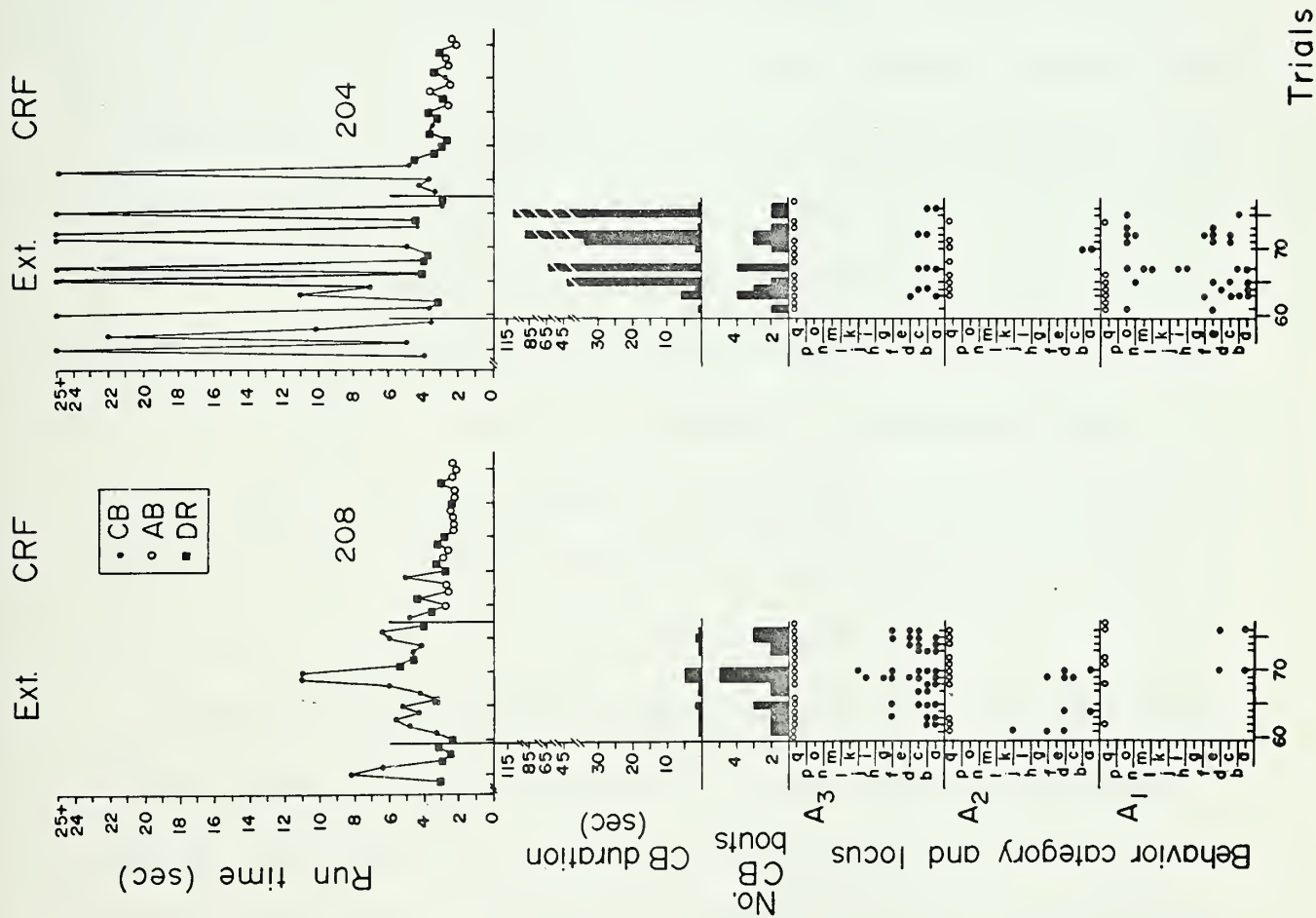
competing behavior, and accessory behavior, occurring throughout the alleyway (Fig. 12). For rats 209 and 213, competing and accessory behavior returned first in A_2 or A_3 , then spread quickly throughout, as for the CRF subjects. Competing behavior also returned first in A_2 for rat 205, but for this subject competing behavior occurred much more often in A_1 than in latter parts of the alleyway. However, accessory behavior was as widespread for rat 205 as for the other CRF-S subjects. There were no novel competing behaviors in extinction (Table 18), and no accessory behaviors which did not occur in acquisition, at least in competing form (Table 19). Also, the range, rank-order, and relative frequency of the competing and accessory behaviors were much the same as in acquisition. The frequency of accessory wall-sniffing increased, as for Gp CRF, and accessory R(C) occurred for the first time, for rat 209. Still, two categories of accessory behavior seen in Experiment I did not occur here for either continuously rewarded group (R(T) and R(W)).

There are two further points of interest about extinction following continuously rewarded acquisition, with or without extra stimuli, which can be seen clearly in the individual data in Figs. 11 and 12. Five of the six subjects of Gps CRF and CRF-S showed some spontaneous recovery of running on the second session of extinction. Trial 63, the first trial of the second day of extinction, was a DR or AB trial faster than the preceding trial (usually a CB trial) for all except rat 209. Further, for all of these subjects except rats 203 and 206, a comparable spontaneous

recovery effect can be seen on the third day of extinction, between trials 66 and 65. Spontaneous recovery may occur still later in extinction, as can be seen for individual subjects across the remainder of extinction. Second, it is seen in Figs. 11 and 12 that for individual subjects extinction following continuously rewarded acquisition appeared to be a cyclic, non-monotonic process, independently of any spontaneous recovery effects. Run time typically increased abruptly from 3-4 sec. or less to 20-25 sec. or more in 1-2 trials. These long CB trials were followed by much shorter CB trials, or less frequently by AB or DR trials, singly or in runs. Since the cycles for different individuals did not show the same periodicity and were not exactly in phase (Figs. 11 and 12), averaging times across subjects obscures the effect, making the increase in run time in extinction appear more smooth and gradual (see Table 20). While long extinction trials did look like long early acquisition trials, shorter extinction trials after the initial breakdown in running differed from shorter trials later in acquisition in one important respect: in the absence of the selection for running, a high frequency of competing and accessory behavior was still seen in A_3 on both the long and the shorter extinction trials (as on shorter PRF acquisition trials for rat 204, and especially rat 208, Fig. 10). This can be seen in Figs. 11 and 12 (e.g., rat 201, trials 66-74; rat 206, trials 71-77; rat 209, trials 76-77; and rat 213, trials 70-71).

The behavior of the PRF subjects in extinction, shown in Fig. 13, looked like their behavior in acquisition. Rat 210 showed no decrement in

Fig. 13. Behavior in Extinction for Gp PRF.



Trials

running across the 42 nonrewarded trials; all of the first 18 extinction trials and 23 of the subsequent 24 extinction trials were fast DR trials. Rat 211 showed slightly more variability in run time than was typical of acquisition, and showed a few fast CB trials after about 20 nonrewarded trials, but fast DR trials still predominated throughout the 42 extinction trials. Rats 204 and 208 continued to show the overall variability, and the corresponding high frequency of competing and accessory behavior which had characterized their performance in acquisition. Overall run time increased slightly in extinction for both of these subjects. Rat 208 showed a strong A_3 bias in competing and accessory behavior in extinction. Rat 204 showed a similar A_3 bias in accessory behavior, but competing behavior was most prominent in A_1 . No novel competing or accessory behaviors occurred in extinction for the PRF subjects (Tables 18 and 19). In sum, for the PRF group as a whole the decrement in running during extinction was very slight (greater resistance to extinction), and there was essentially no decrement for those subjects who showed the least disruption, and the fastest, most stable run times, in acquisition.

During CRF reacquisition following extinction for rats 204 and 208 of Gp PRF (trials 78-101), run time and overall variability decreased (Fig. 13). After a few CRF sessions, relatively fast and stable AB and DR runs predominated, suggesting strongly that the erratic performance of these subjects in acquisition was in fact due to the PRF schedule.

The high level of competing and accessory behavior throughout the

Table 21

Proportion of CB and AB Trials Showing Intra- and Inter-
Individual Behavior Sequences, and Proportion of
Sequences Occurring in A₃, During Extinction
in Experiment II

Subjects	Intra-Individual		Inter-Individual	
	Overall	(A ₃)	Overall	(A ₃)
<u>Gp CRF</u>				
201	.19	0	0	-
203	.38	0	.06	0
206	.13	0	.13	0
\bar{X}	.23	0	.06	0
<u>Gp CRF-S</u>				
205	.60	0	.07	0
209	.38	0	.19	0
213	.20	0	.07	0
\bar{X}	.39	0	.11	0
<u>Gp PRF^a</u>				
204	1.00	(.17)	.06	0
208	.83	(.20)	.11	0
\bar{X}	.92	(.19)	.09	0

^aRats 210 and 211 showed no competing or accessory behavior during extinction.

alleyway in extinction for all subjects was associated with a relatively high frequency of intra-individual behavior sequencing, as is shown in Table 21. The frequency of inter-individual sequencing was still quite low. For most subjects the frequency of both kinds of recurrent sequences increased from acquisition. Of the behavior sequencing which occurred, very little involved A_3 sequencing, as in acquisition.

Discussion

The results of this experiment show that the great increase in run time with the removal of reward following continuously rewarded acquisition in the alleyway reflects the rapid return of competing and accessory behavior, and not a simple decrease in the rate of running (Bindra, 1961; Estes, 1950, 1959; Guthrie, 1959; Marx & Brownstein, 1963; McCoy & Marx, 1965; Miller & Miles, 1936; Miller & Stevenson, 1936; Wendt, 1936). For both Gp CRF and Gp CRF-S, this noninstrumental behavior returned first in the latter parts of the alleyway and spread quickly throughout. This is in contrast to the return of competing and accessory behavior with reward magnitude downshifts or an extra stimulus, which generally occurs first and most prominently in A_1 , as shown in Experiment I. Consistent with the present extinction results, Bruce (1935) found that, when food reward for hungry rats and water reward for thirsty rats were switched, "exploratory" behavior returned first in the latter parts of a maze before spreading quickly throughout. For both groups of

continuously rewarded rats, the categories of competing and accessory behavior seen here in extinction were the same as those seen in acquisition, though individual subjects sometimes showed a wider range of behaviors in extinction than they had in acquisition. Also, the rank-order and relative frequency of the categories of competing and accessory behavior generally varied little from acquisition to extinction. Thus, the return of competing and accessory behavior with extinction, as with other experimental manipulations, appears to reflect a stable, organized hierarchy of variable behaviors from which behaviors seen initially in training also derive. It seems clear that competing and accessory behaviors in extinction reflect neither a simple within-subjects "regression" to earlier behavior patterns (Miller & Stevenson, 1936) nor the elicitation of "novel" behaviors specific to nonreward (e.g., frustration-elicited behaviors, Amsel, 1958; Spence, 1960). These extinction results are consistent with the general view of the alleyway as a selective learning situation outlined in Experiment I.

The prediction that continuously rewarded subjects exposed to extra stimuli in acquisition which engender competing behavior would show greater resistance to extinction received some support. Gp CRF-S showed slightly greater initial resistance to extinction than Gp CRF, due largely to one CRF-S subject, rat 205. There was no consistent difference between the two groups later in extinction except that the CRF-S subjects again showed somewhat more resistance to extinction across the last two

sessions, mainly due to the extremely long run times for rat 203. Though these results suggest, consistent with other alleyway results (e.g., McNamara & Wike, 1958; Robbins, 1971), that inducing competing behavior in acquisition may be sufficient to retard extinction, the relatively small extinction differences between the two groups do not seem commensurate with the great differences in the amount of competing and accessory behavior in acquisition.

It is clear that the extinction of running following continuously rewarded acquisition (Gps CRF and CRF-S) is a nonmonotonic process; after an abrupt initial increase in run time, much faster trials returned, singly or in runs. Spontaneous recovery from the last trial of one session to the first trial of the next, seen here to be a reliable, single-subject phenomenon, did not account entirely for this cyclicity of run time in extinction. This cyclicity has been shown repeatedly in free-operant situations (cf., Ferster & Skinner, 1957, pp. 52-63, 346-351, 411-413; Horns & Heron, 1940; Skinner, 1933, 1961), though rarely observed in the alleyway (see Miller & Stevenson, 1936). This reflects the greater focus of free-operant studies on single-subject behavior, albeit automatically recorded. Given that the cycles of individual subjects have different periods and are not exactly in phase, the usual practice of averaging run times across subjects in the alleyway obscures the effect.

Partial reinforcement here had a bi-modal effect in acquisition. Some rats (204 and 208) showed much competing and accessory behavior

throughout acquisition, especially in latter parts of the alleyway, and did not reach a stable asymptote of DR runs even after prolonged training, comprising 59 trials across 22 days. In CRF training after extinction these subjects showed markedly less noninstrumental behavior and increasingly stable run times, suggesting strongly that their erratic performance in PRF acquisition was indeed due to the PRF schedule and not merely to individual idiosyncrasy. Other subjects (rats 210 and 211) showed little competing or accessory behavior in PRF acquisition, and quickly reached a stable asymptote of extremely fast DR runs. If this split proves to be a general outcome, it might help to account for the inconclusive results with PRF acquisition in the alleyway literature, with some studies reporting PRF groups running slower overall than CRF groups at asymptote (see Kimble, 1961, p. 315; Lewis, 1960; Lewis & Cotton, 1957), some finding no difference (Goodrich, 1959, Exp. I; Weinstock, 1954), and some finding faster asymptotic running for PRF groups (Goodrich, 1959, Exp. II; see Robbins, 1971; Weinstock, 1958). Differences in the proportion of PRF subjects showing each kind of adjustment to the partial reinforcement schedule, revealed only through an analysis of single-subject behavior, could easily account for the variable results.

The vastly greater resistance to extinction of the PRF subjects did not depend on partial reinforcement engendering competing behavior in acquisition. While PRF can produce a high level of competing behavior, it does not inevitably do so, and the present results indicate that the PRF

subjects who showed the least competing behavior in acquisition were the most resistant to extinction; rats 210 and 211 showed only about as much competing behavior as the subjects in Gp CRF, yet continued to show fast DR runs, with no decrement in run time, even after 42 nonrewarded trials across 12 days. Thus, the expression of high levels of overt competing behavior in acquisition may be sufficient for greater resistance to extinction (e.g., Gp CRF-S), but it is not necessary.

A recent account of behavioral "persistence" in extinction (Amsel, 1972) predicts that the more a subject comes to run in the presence of a "disruptive" stimulus, the greater his resistance to extinction. This account assumes that it is not the amount of competing behavior expressed in acquisition, but the extent to which running dominates in the presence of disruptive stimuli such as occasional nonreward, which determines resistance to extinction. This kind of account has been applied to the partial reinforcement effect before (Estes, 1959; McNamara & Wike, 1958; Weinstock, 1954). It fits the present PRF results quite well. However, this view should predict that the CRF-S subject who showed the least disruption of running throughout training with extra stimuli (rat 213) would show the greatest resistance to extinction. In fact, rat 205, who showed a large-scale disruption in acquisition, showed by far the greatest initial resistance to extinction in Gp CRF-S.

The PRF subjects showed high levels of A_3 competing and accessory behavior and relatively slow running in A_3 even when no competing or

accessory behavior occurred. Some continuously rewarded subjects of both Gps CRF and CRF-S, unlike the hungry subjects of Experiment I, showed behavior with very similar structure. These apparent behavioral interactions were largely independent of any overt inter-individual sequencing. Previous experiments have suggested similar interactions at a very gross level, in terms of slowing of overall run speed near the goal, between control subjects and subjects receiving nonreward or reduced reward (Ludvigson & Sytsma, 1967; McHose & Ludvigson, 1966). In addition to such interactions between the partially and continuously rewarded rats, the observation of single-subject behavior in both experiments reported here revealed recurrent behavior sequences between subjects, and occasional periods of long run times for several subjects, not involving inter-individual sequencing. Although these interactions all appear to involve odor tracing, especially since floor- and wall-sniffing are so prominent, and communication via other sensory systems can be virtually ruled out, their chemical and physiological mechanism is not at all understood. Overall, it is certainly clear from these observations that the behavior of an individual rat is not entirely independent of the behavior of other rats run concurrently in the alleyway.

There is evidence that the structure of behavior observed here in extinction was not an artifact of these poorly understood between-subject interactions. Pilot experiments running individual subjects through CRF acquisition and extinction by themselves have found the same results reported in detail here (Kello, unpublished observations).

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BIOGRAPHY

Name: John Edward Kello

Born: September 12, 1946, Norfolk, Virginia.

Education: Old Dominion College, 1964-1968, B.S., summa cum laude, in psychology.
Duke University, 1968-present, M.A. (1970),
in psychology.

Honors: Norfolk City School Board Scholarship to ODC
(1964-1966).
ODC Faculty Scholarship (1966-1968).
Member, Delta Phi Omega honorary scholastic
fraternity (1967).
Awarded competitive Biomedical Sciences
Support Grant from Duke University for
summer research, 1969-1972.
Associate Member, Sigma Xi.

Research and Teaching Positions: Psychology Assistant in human factors laboratory,
Naval Safety Center, Norfolk, Virginia,
1967-1968.
Tutor, Duke University, in junior-senior level
tutorial on S-R approaches to frustration,
Spring Semester, 1971.
Teaching and laboratory assistant, Duke
University, for Dr. J. E. R. Staddon:
undergraduate learning course, 1970 and 1971;
undergraduate seminar in adaptive behavior,
1971.

Publications:

Kello, J. E. The reinforcement-omission effect on fixed-interval schedules: Frustration or inhibition? Learning and Motivation, 1972, 3, 138-147.

Kello, J. E. Response "momentum" on two-valued cyclic-interval schedules. Submitted for publication.





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